

Mars Exploration Rovers: 4 Years on Mars

Geoffrey A. Landis

This January, the Mars Exploration Rovers "Spirit" and "Opportunity" are starting their fifth year of exploring the surface of Mars, well over ten times their nominal 90-day design lifetime. This lecture discusses the Mars Exploration Rovers, presents the current mission status for the extended mission, some of the most results from the mission and how it is affecting our current view of Mars, and briefly presents the plans for the coming NASA missions to the surface of Mars and concepts for exploration with robots and humans into the next decade, and beyond.

Four Years on Mars: the Mars Exploration Rovers



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<http://www.sff.net/people/geoffrey.landis>

Presentation at MIT Department of Aeronautics and Astronautics, January 18, 2008

Exploration - Landis

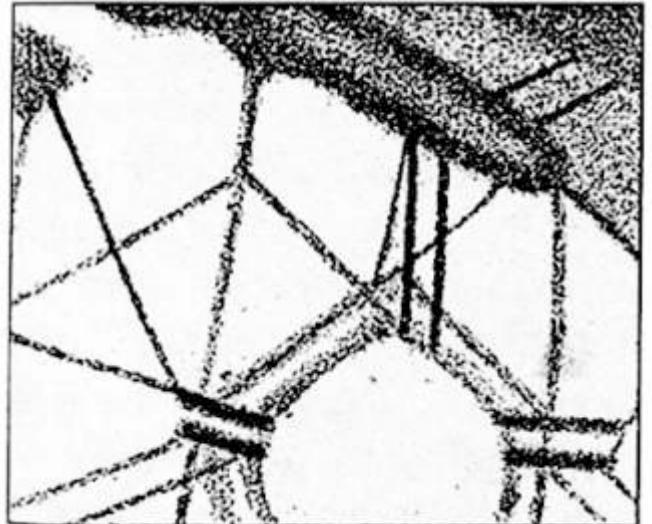
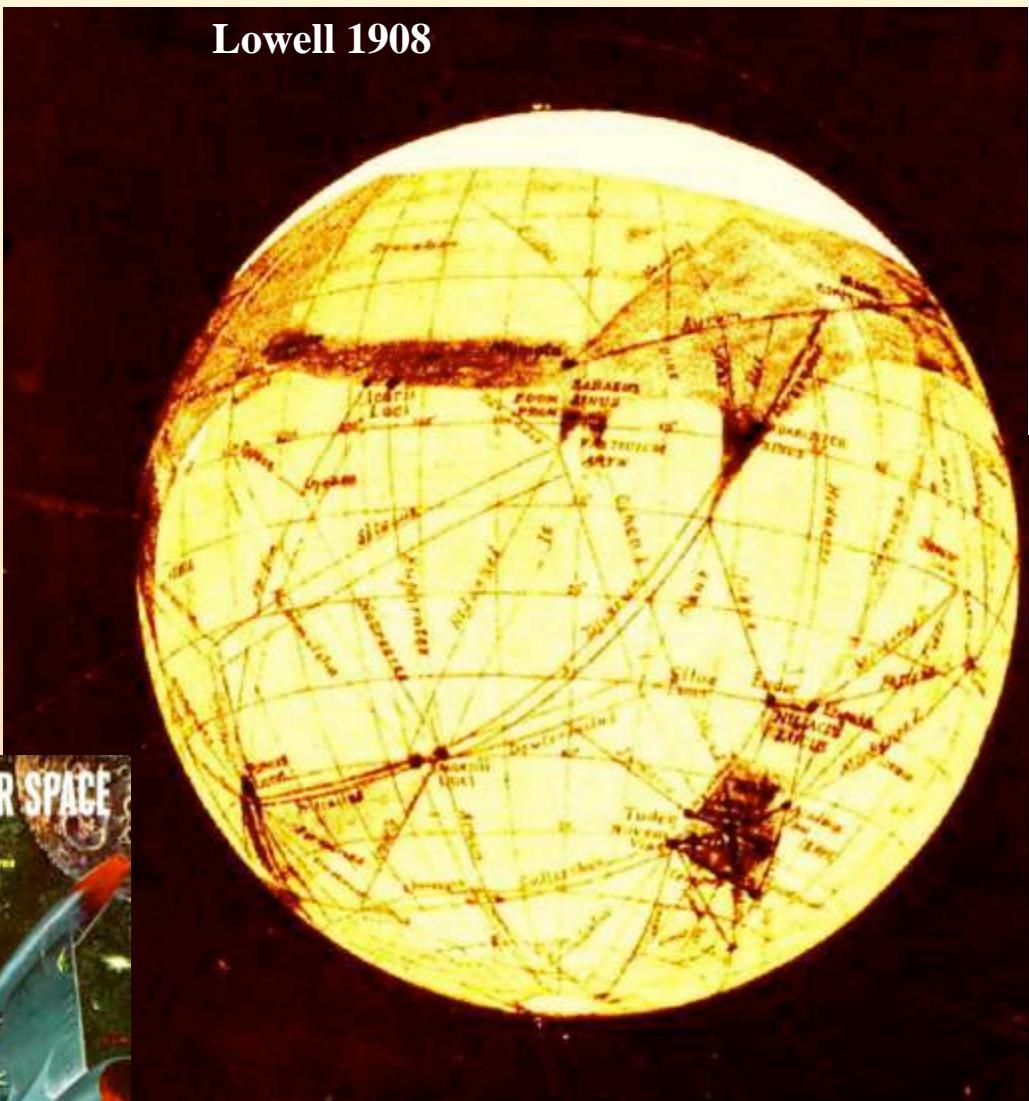


Mars viewed from the Hubble Space Telescope

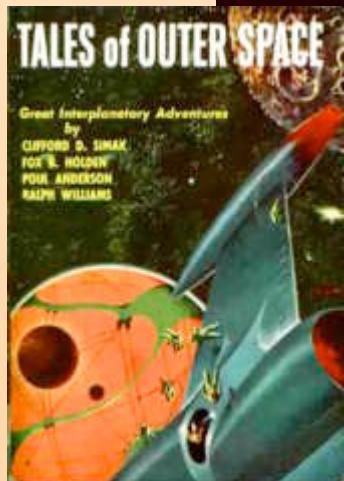
Exploration - Landis

Views of Mars in the early 20th century

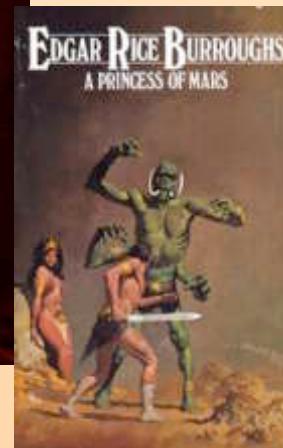
Lowell 1908



Sciaparelli 1888



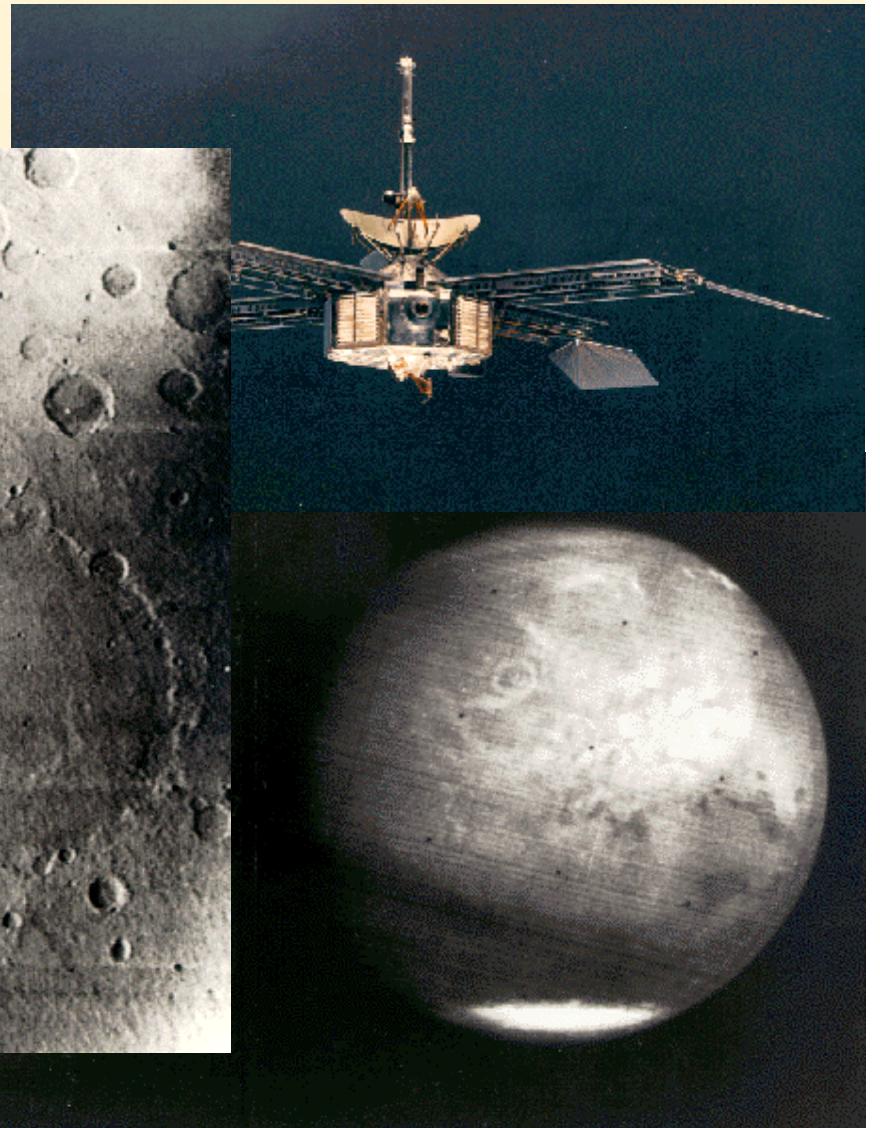
Tales of Outer Space ed. Donald A. Wollheim, Ace D-73, 1954
(From Winchell Chung's web page projectrho.com)



Burroughs 1912
(cover painting by Frazetta)

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Past Missions to Mars: *first close up images of Mars from Mariner 4*



Mariner 4 discovered Mars
was a barren, moon-like desert

Viking 1976

Signs of past water on Mars?

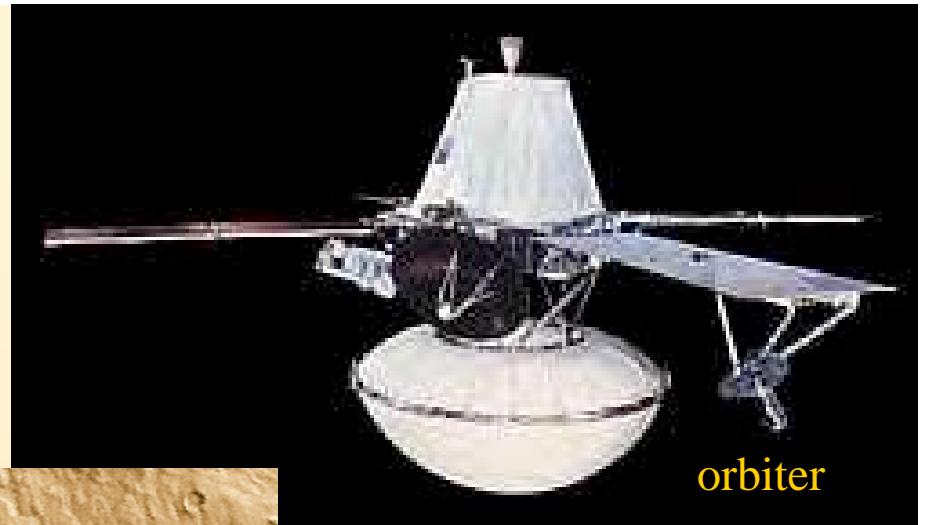


Photo from orbit by the
1976 Viking orbiter

Pathfinder and Sojourner Rover: a solar-powered mission to Mars

July 1996

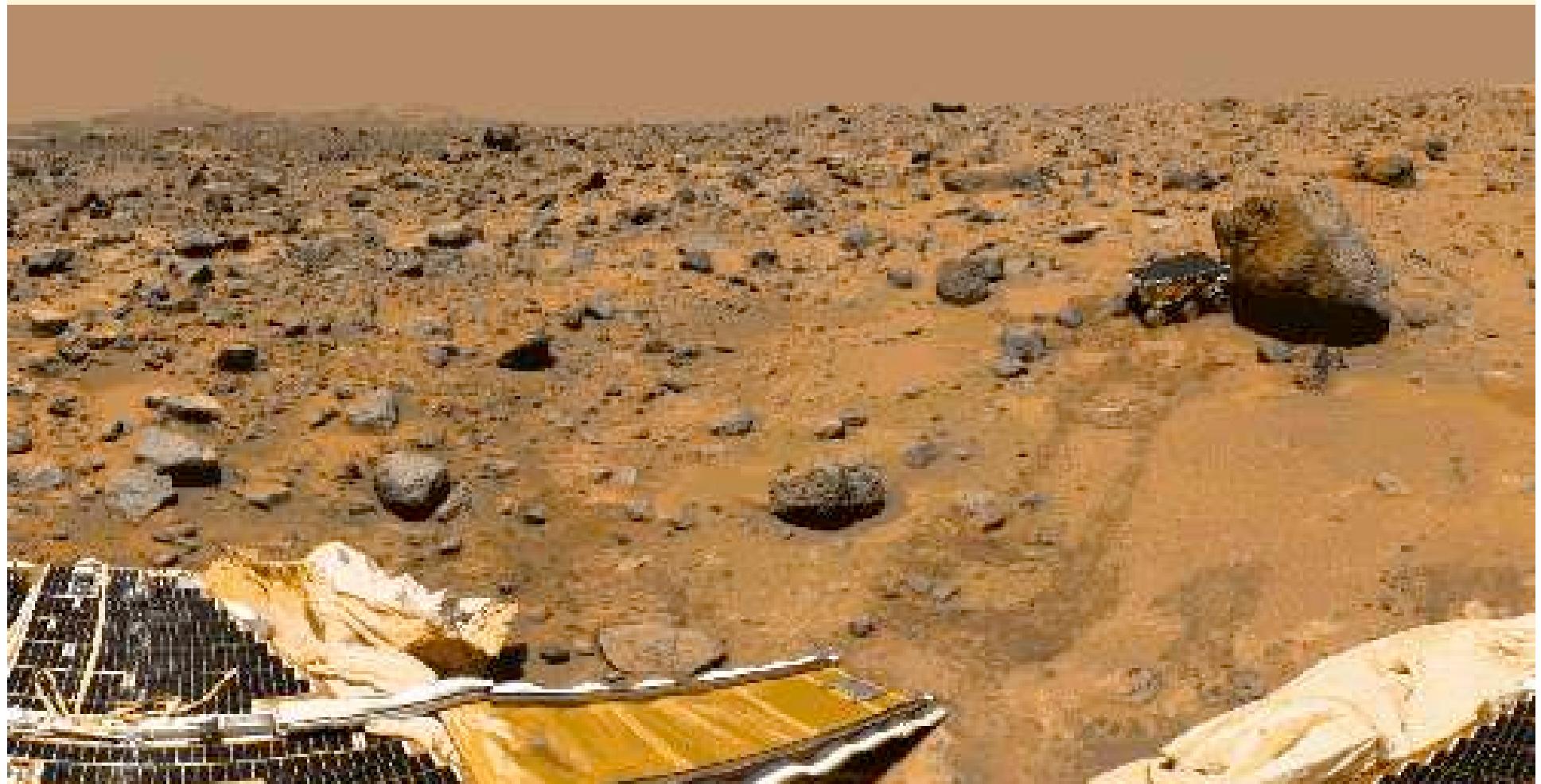
The Sojourner rover was about the size of a Cocker Spaniel

Geoff Landis poses with the Sojourner rover

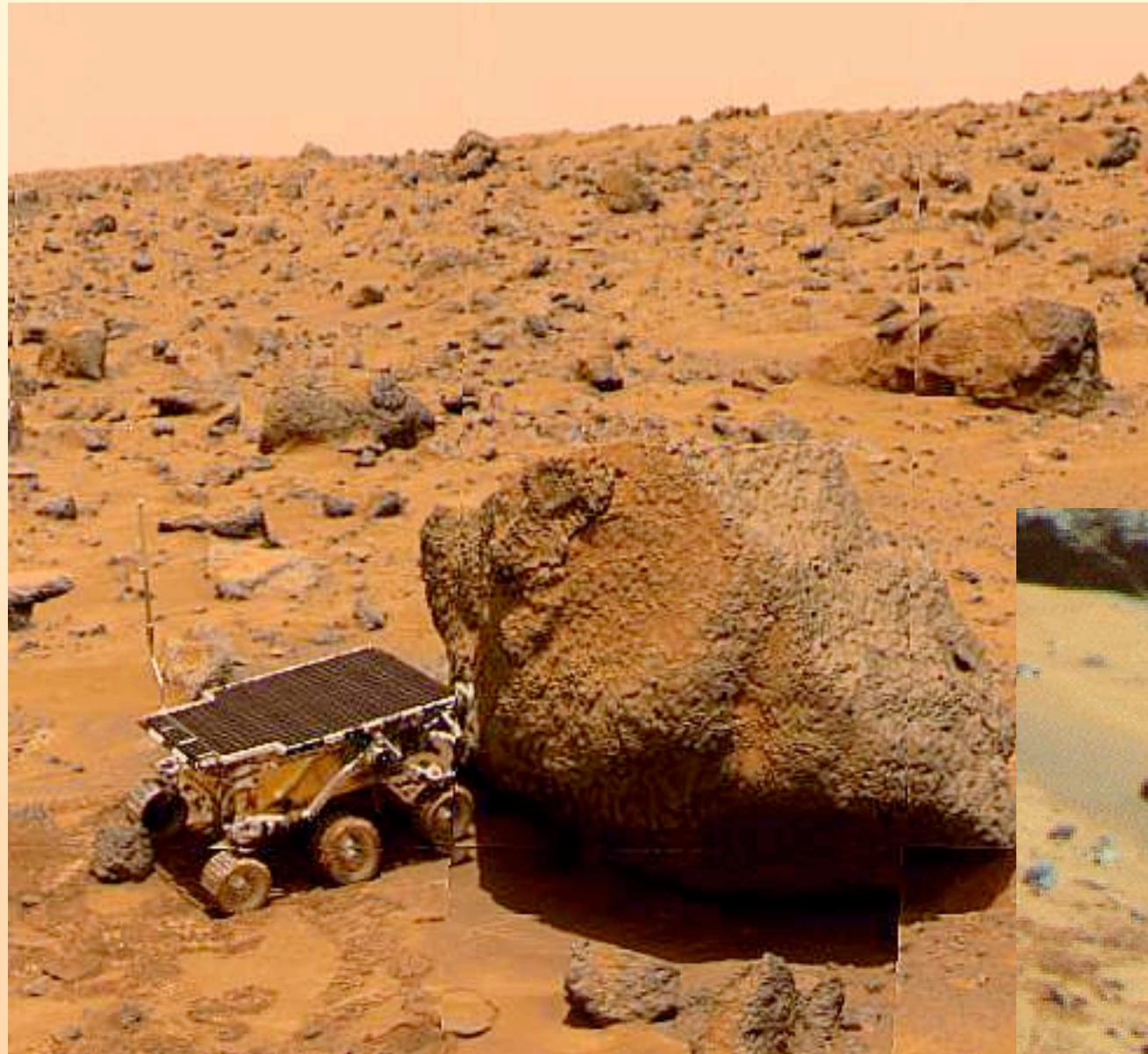


Exploration - Landis

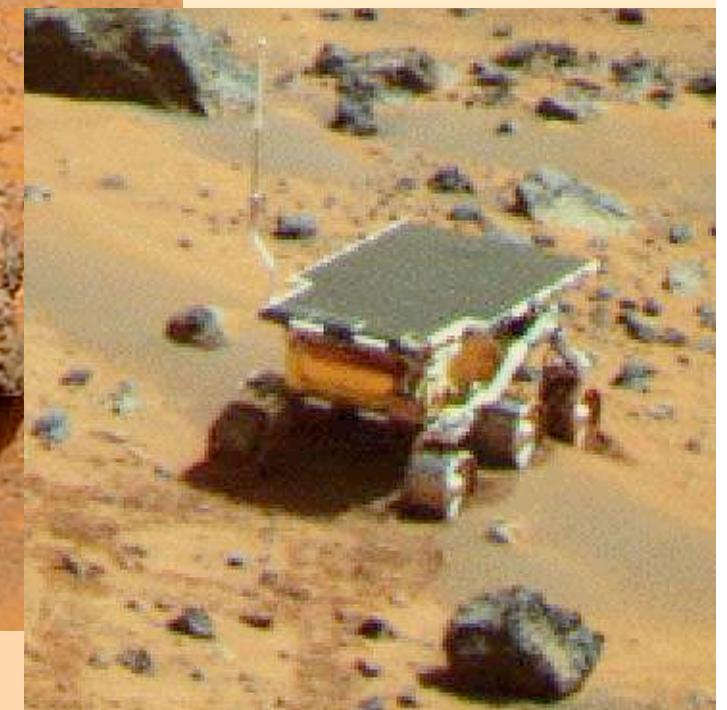
Sojourner: down the ramp and exploring Mars



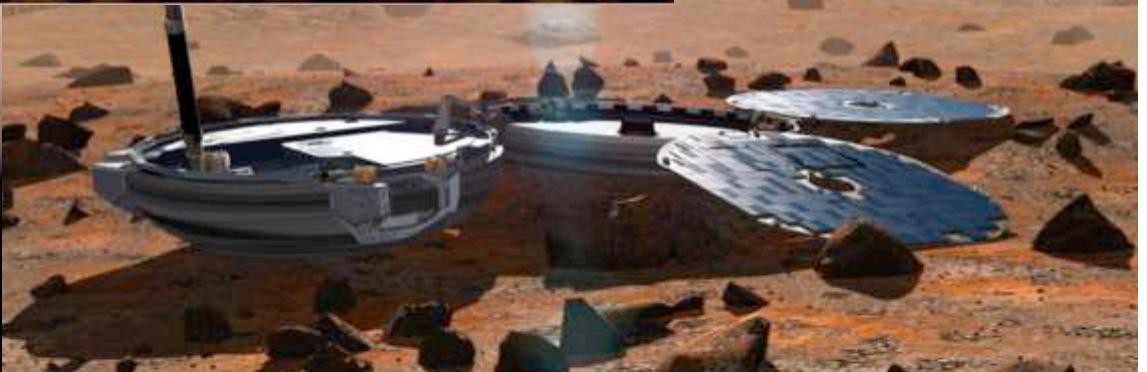
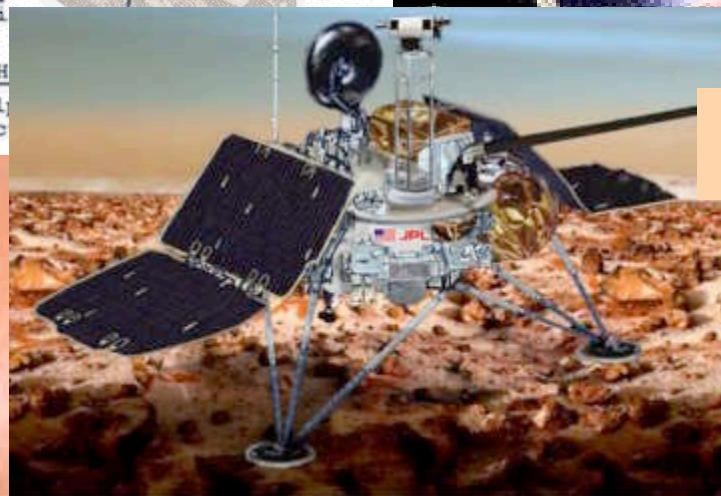
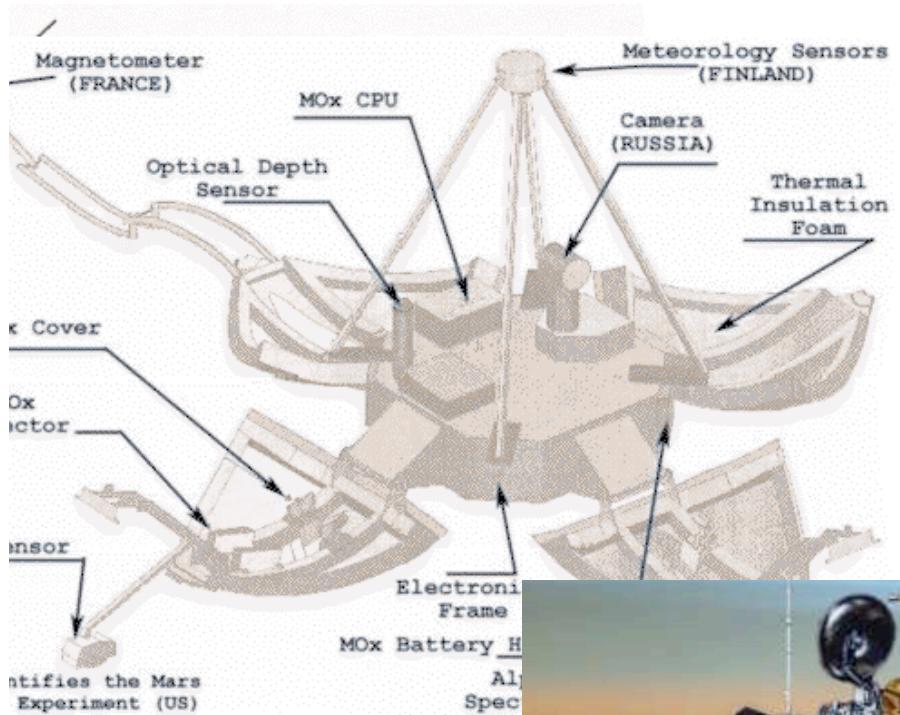
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Sojourner on
Mars!



Exploration - Landis



Failed missions to Mars

Mars Climate orbiter
Mars 96, Nozomi,
Beagle-2,
Mars Polar Lander



Spirit launch

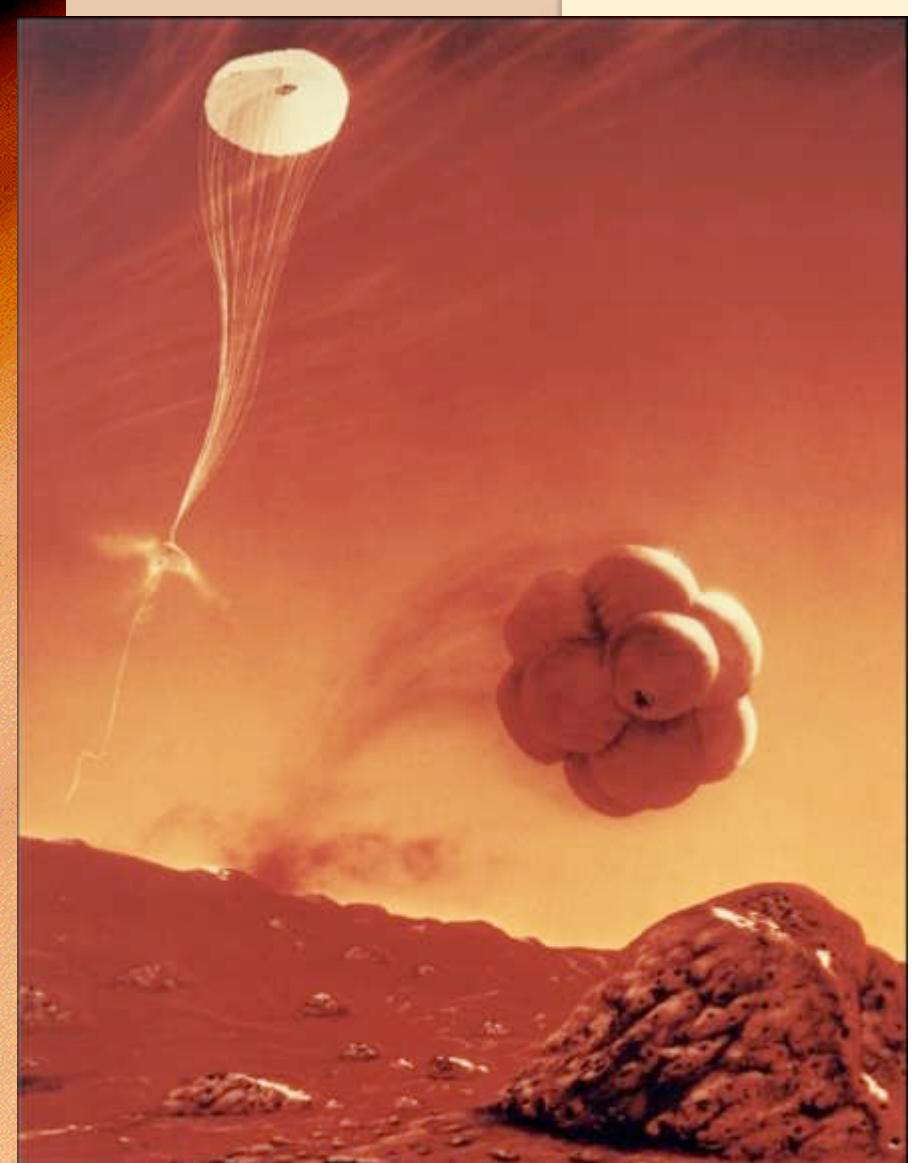
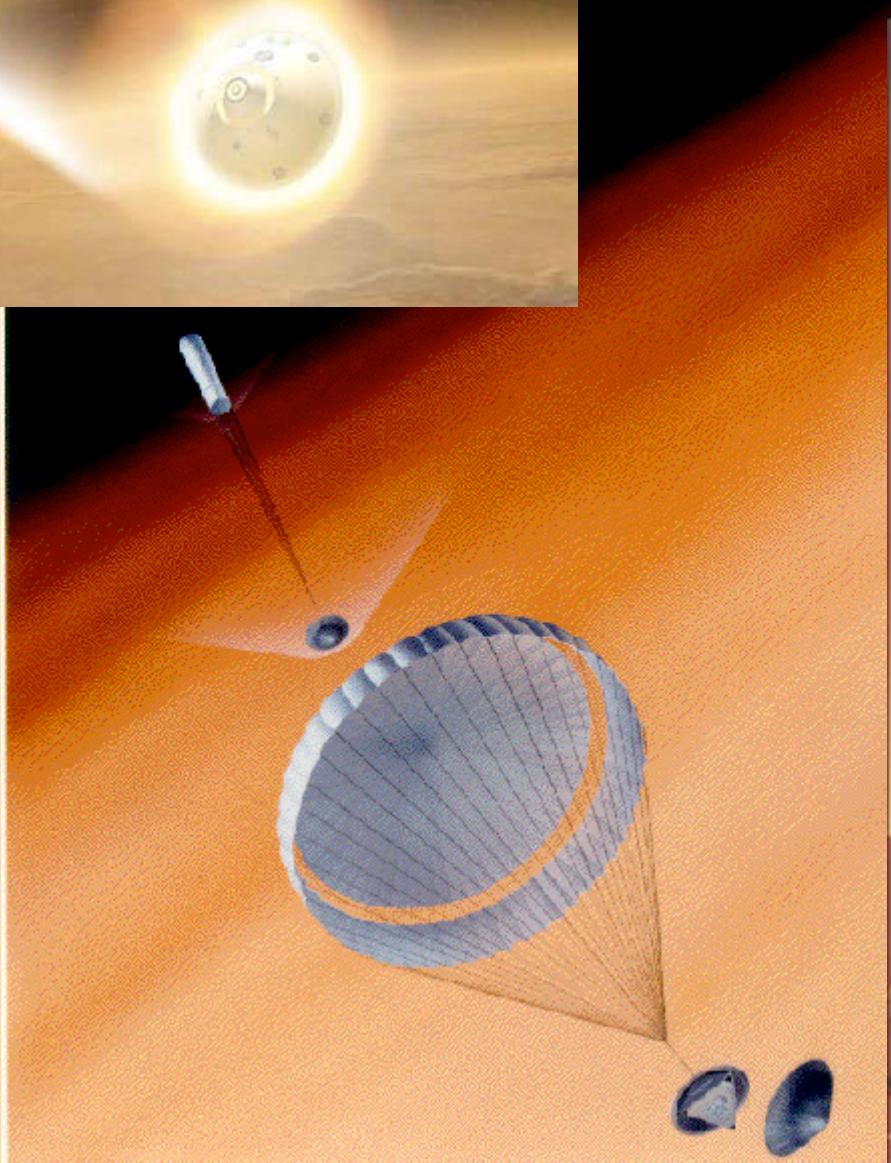
Exploration - Landis

Night launch of MER B "Opportunity" in July 2003

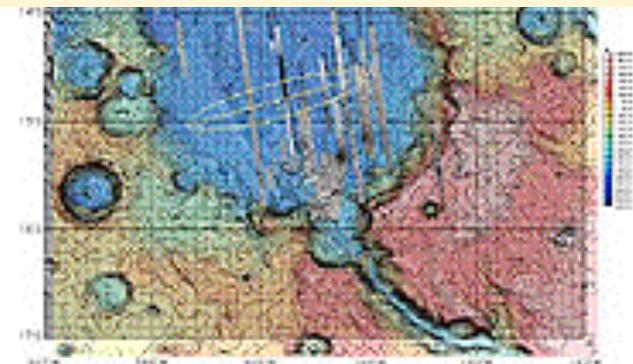
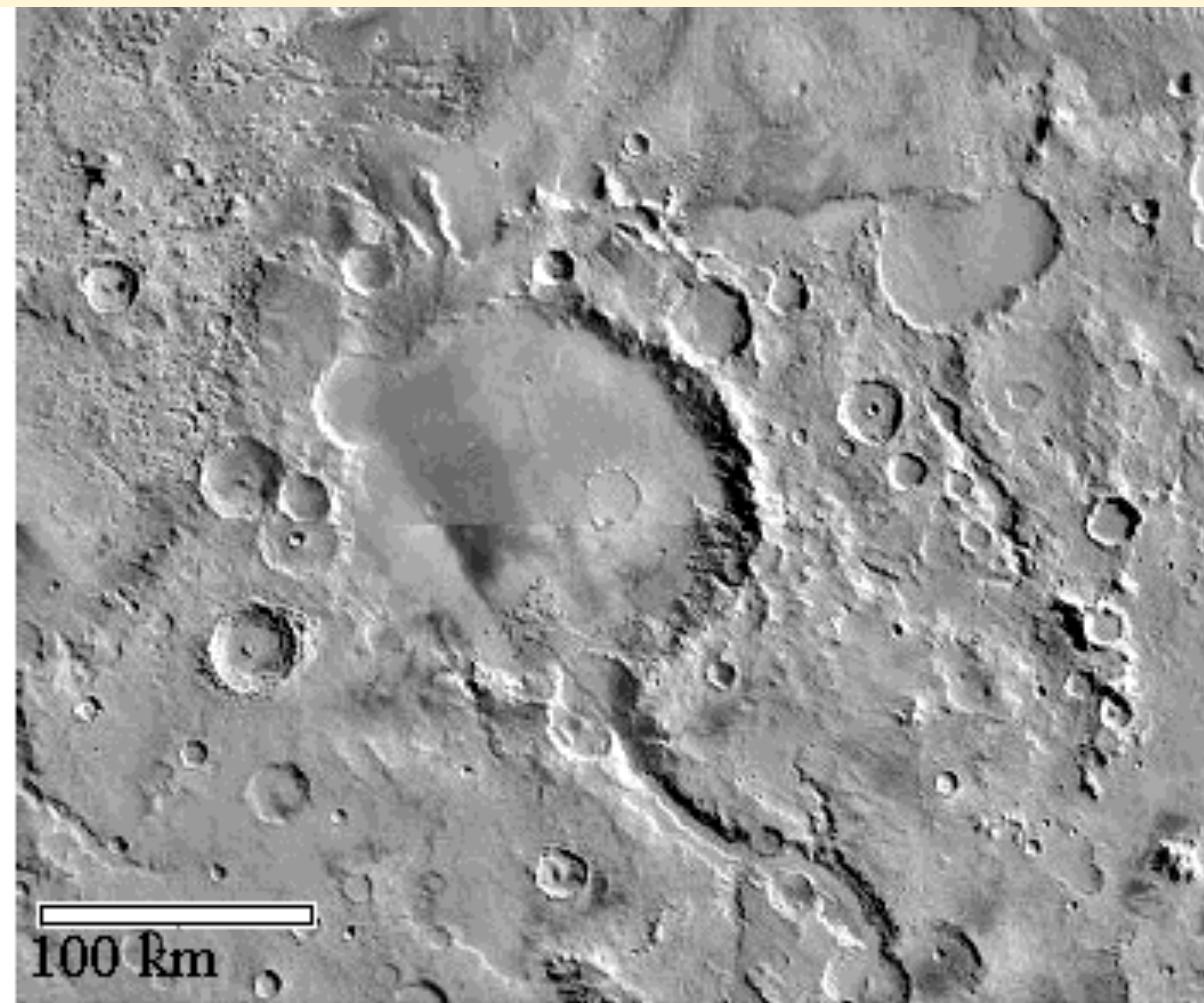




"bouncedown"
airbag landing on Mars



Spirit landing site



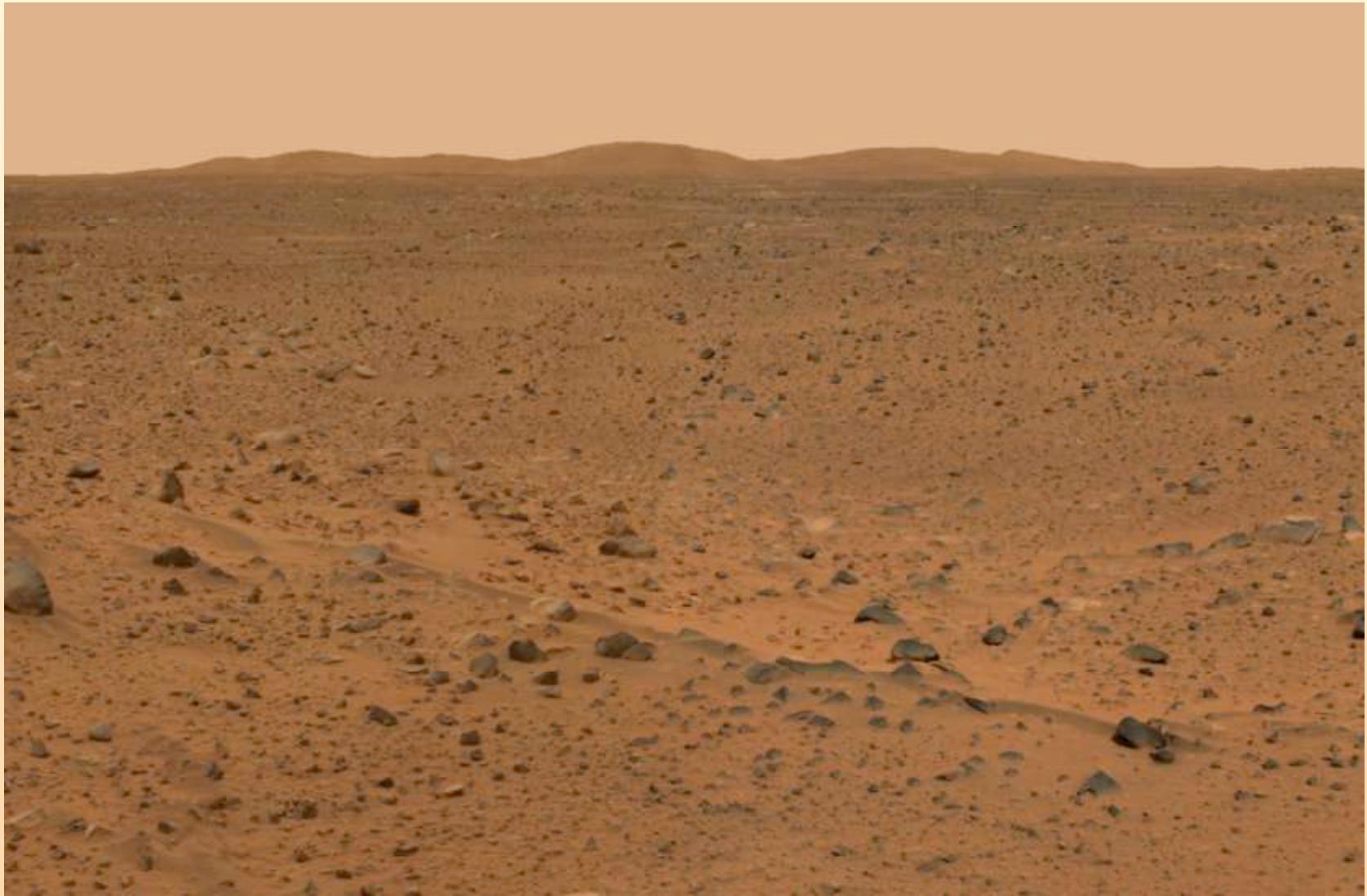
Gusev Crater
landing site: a
Martian dry lake
bed

left: Viking orbiter image

The NASA Mars exploration strategy:
“Follow the water!”

Exploration - Landis

Gusev crater landing site

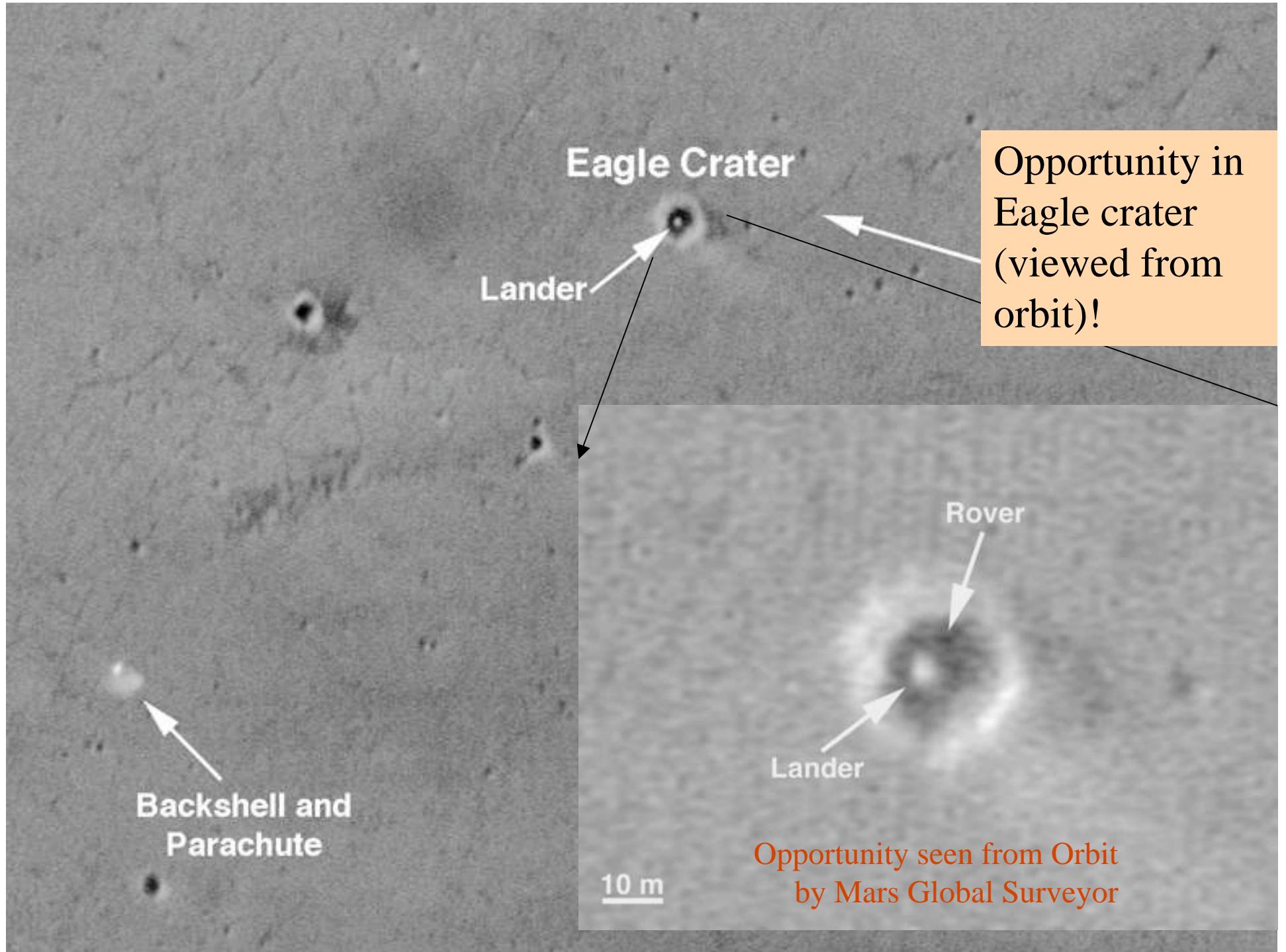


First view of the site after the landing: rocks, sand, and mountains

Opportunity Rover landing



Landing trajectory with bounces:
hole in one!



Eagle Crater--View from Opportunity



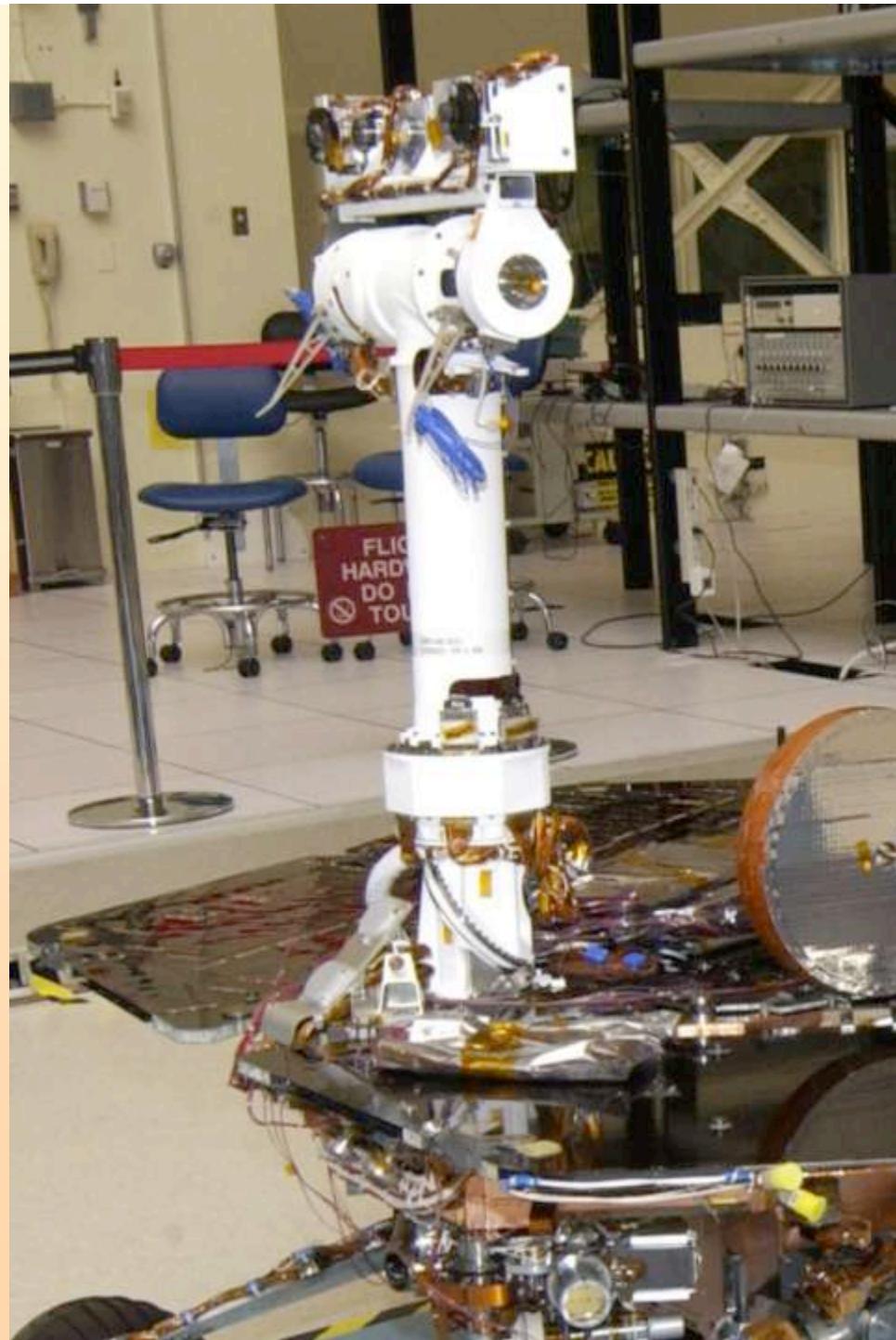
Exploration - Landis

Opportunity Outcrop "El Capitan"



Note: Colors are stretched

Pancam mast assembly



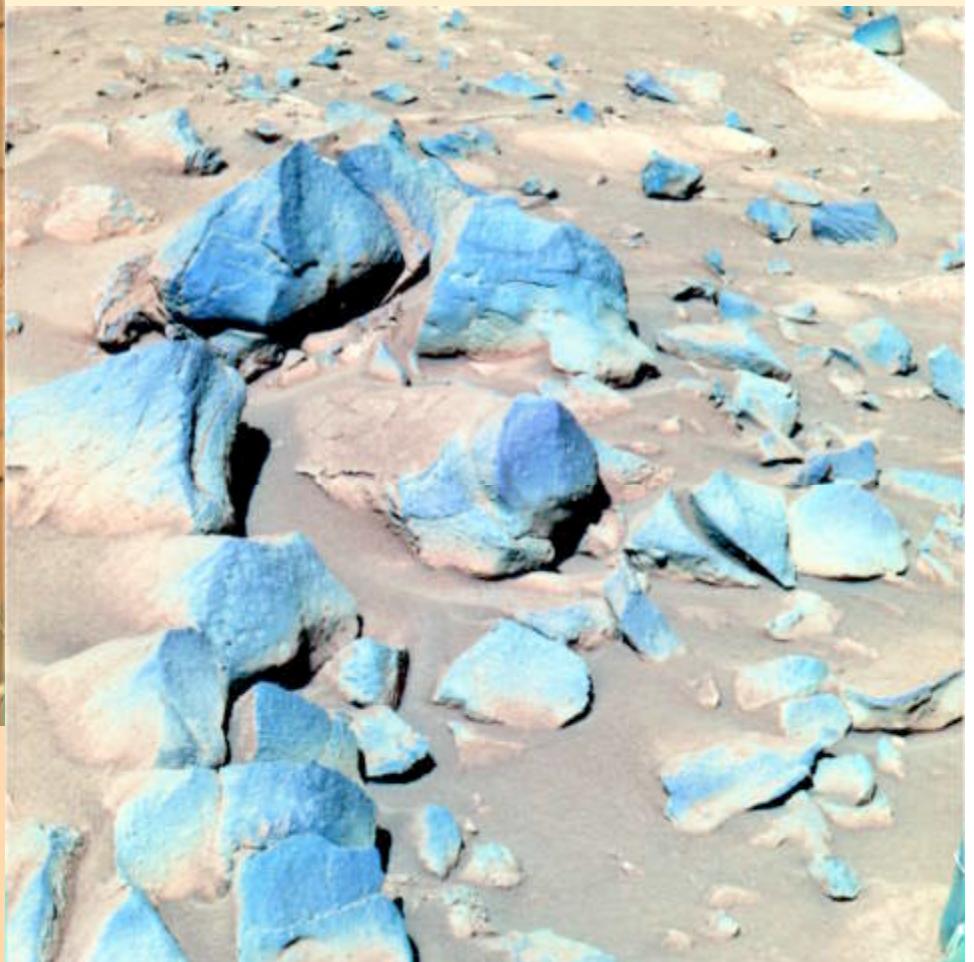
ndis

True color: what your eye would see



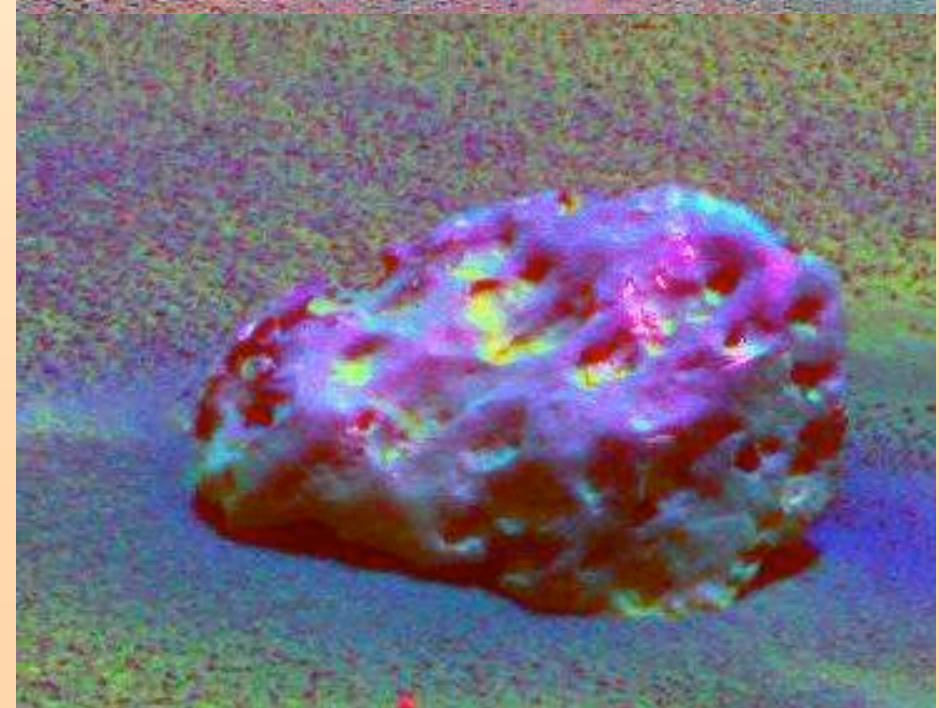
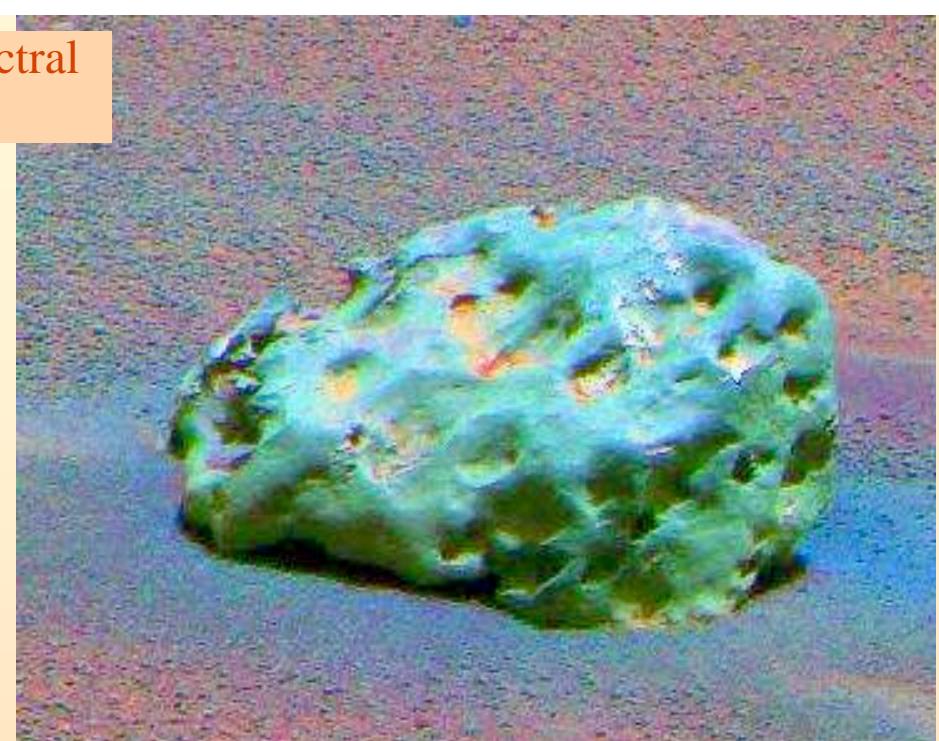
Color of Mars

Stretched color:
enhanced to bring out mineralogy

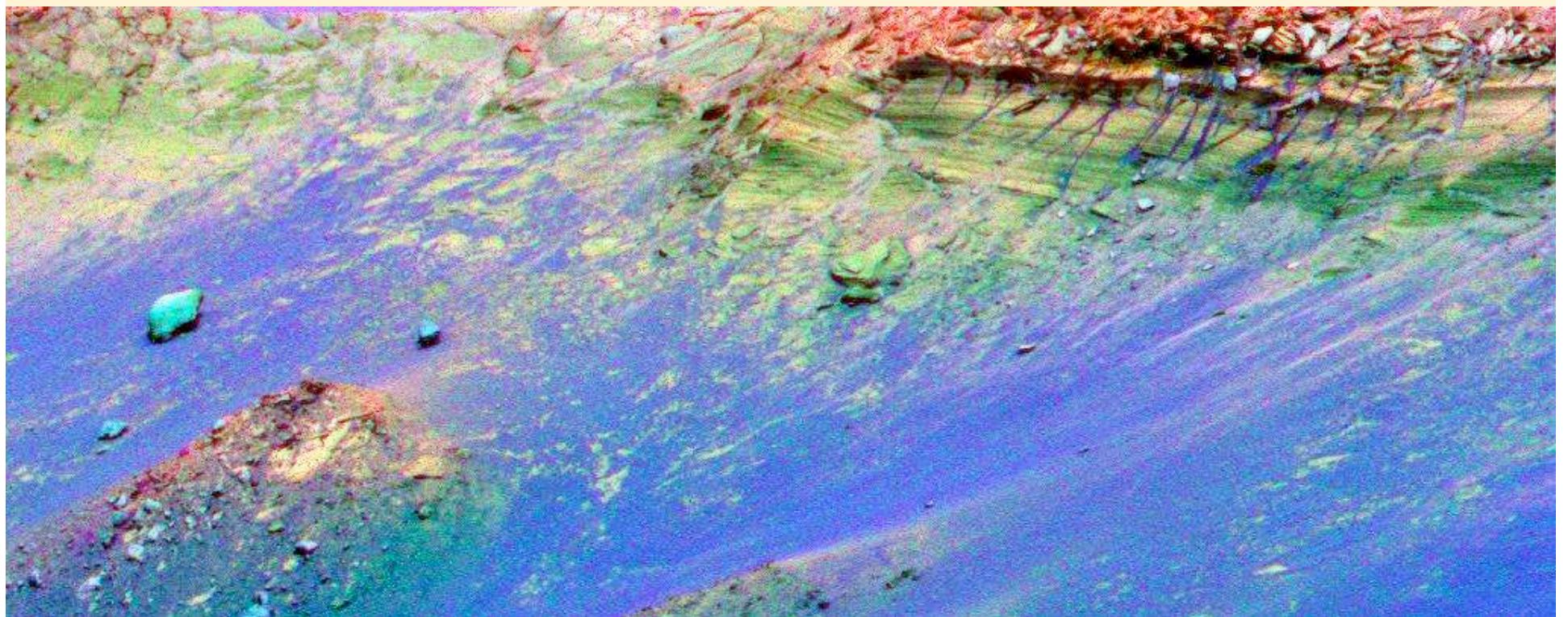


Mars is primarily adobe-orange in color. The geologists usually enhance the color contrast so that subtle differences in color of different minerals can be seen

Pancam "Decorrelation" stretch: different spectral contrast bring out different features



Pancam R126 decorrelation stretch Endurance



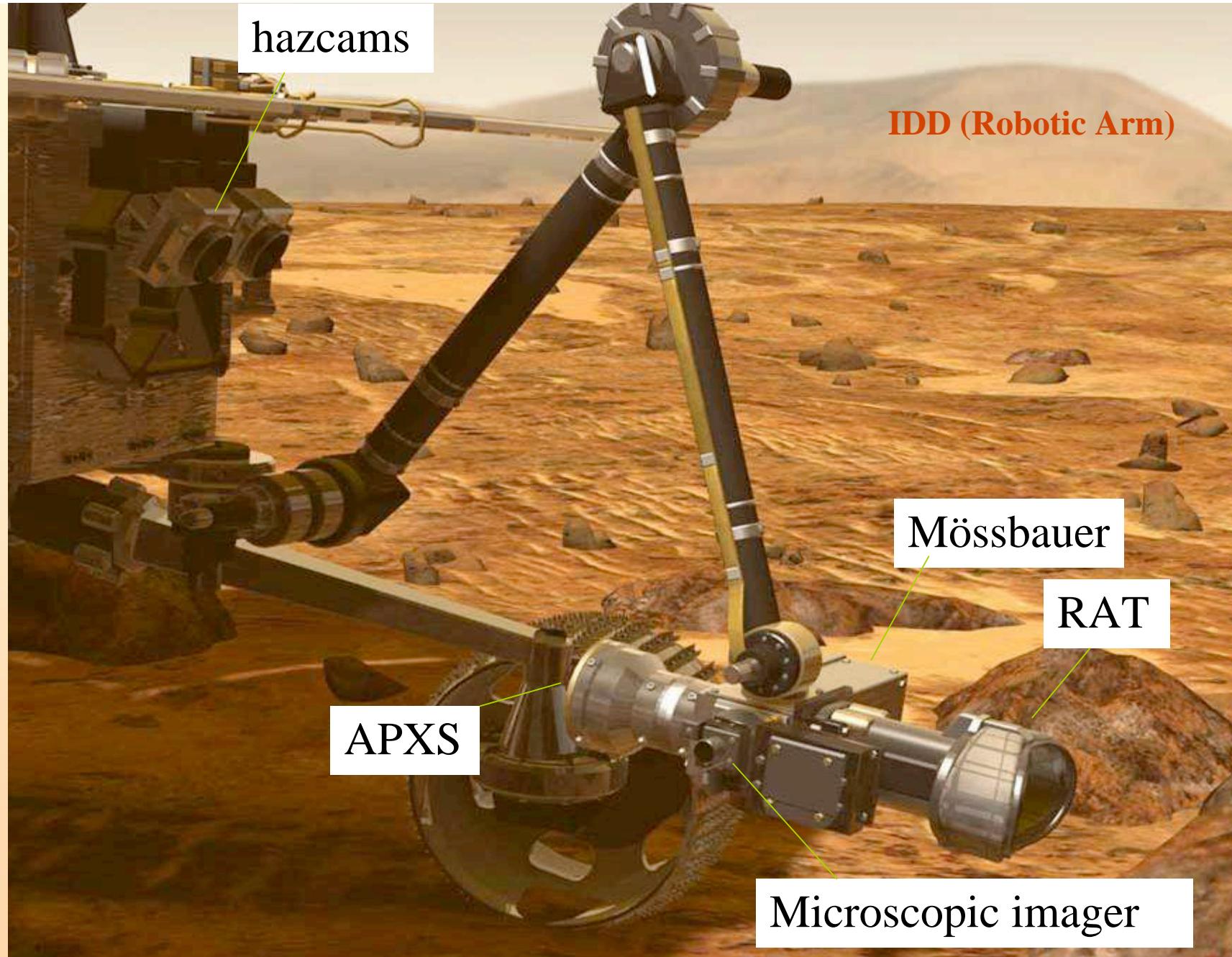
(courtesy Bill Farrand, Sol 271)

R126 = "blue, red, infrared"

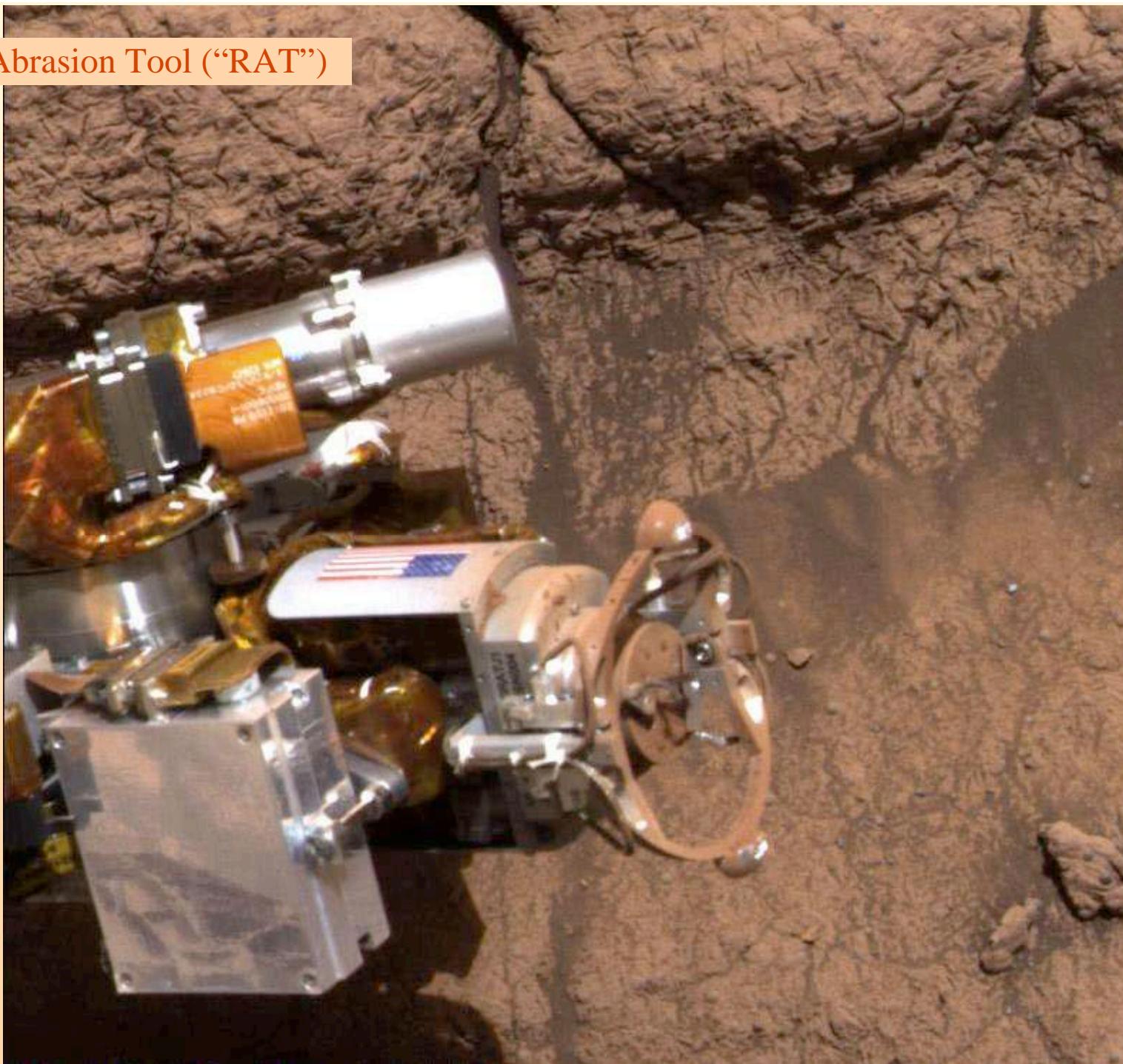
R1 - 430 nm

R2 - 750 nm

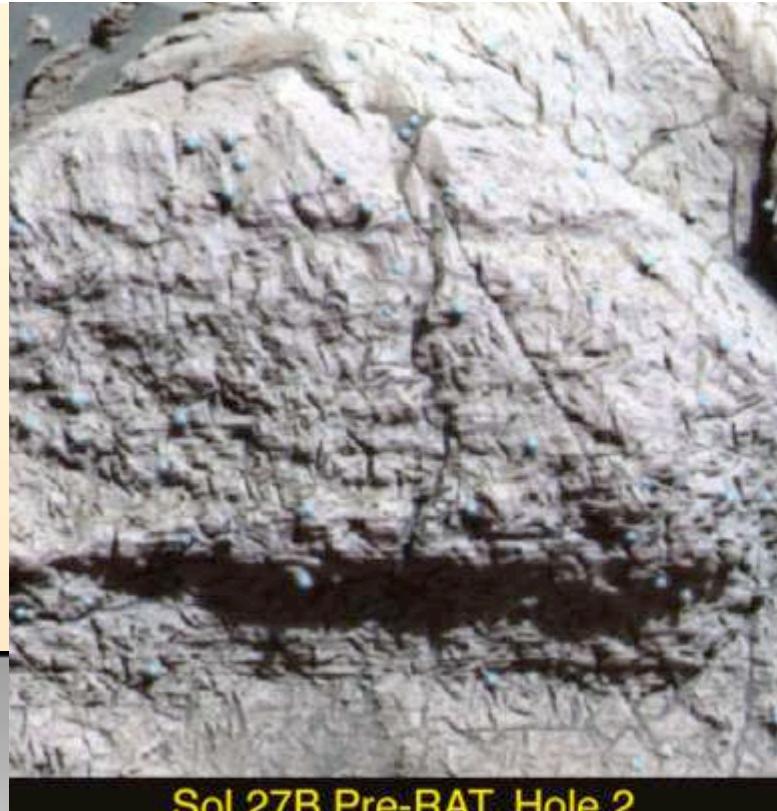
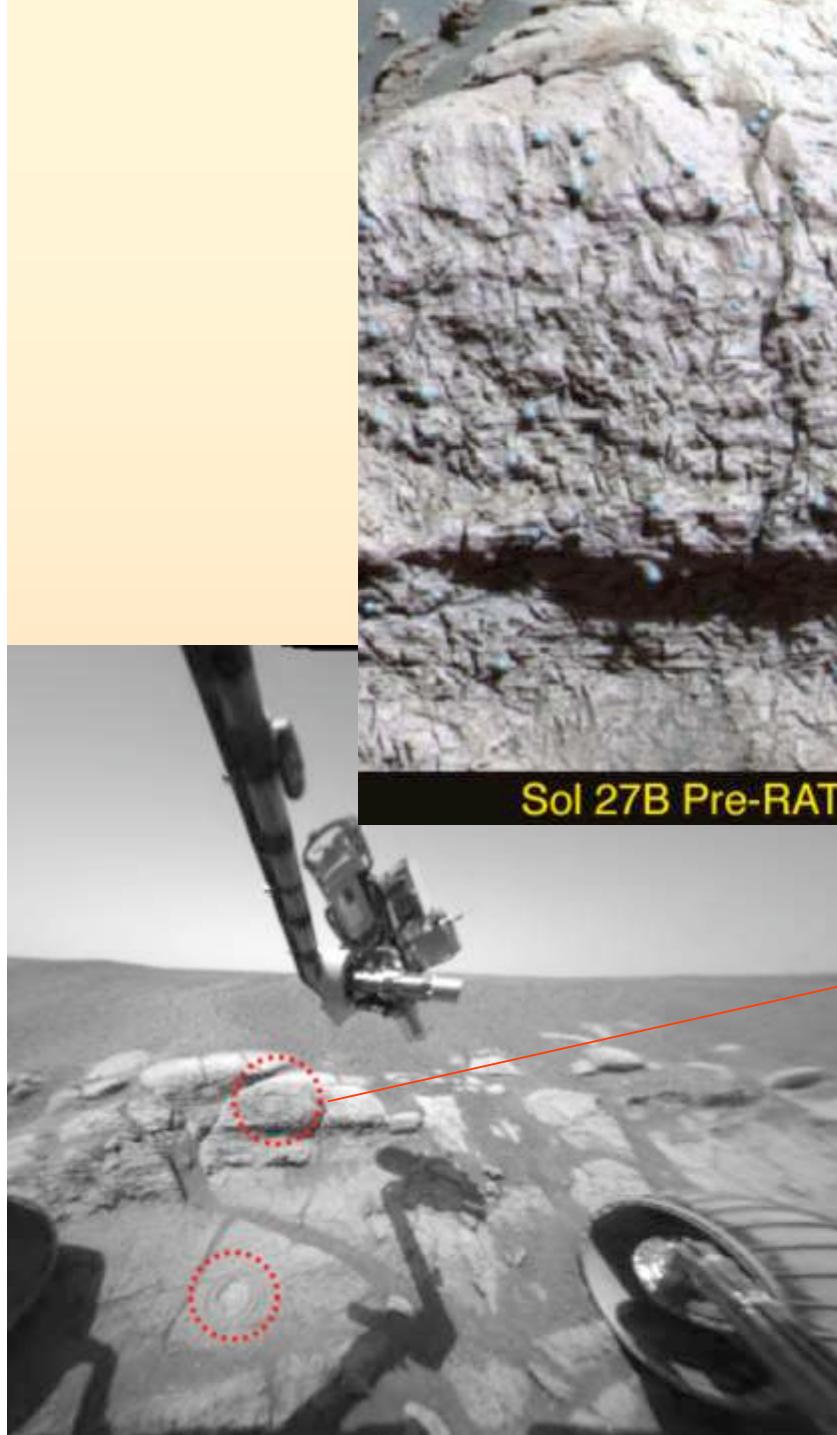
R6 - 930 nm Exploration - Landis



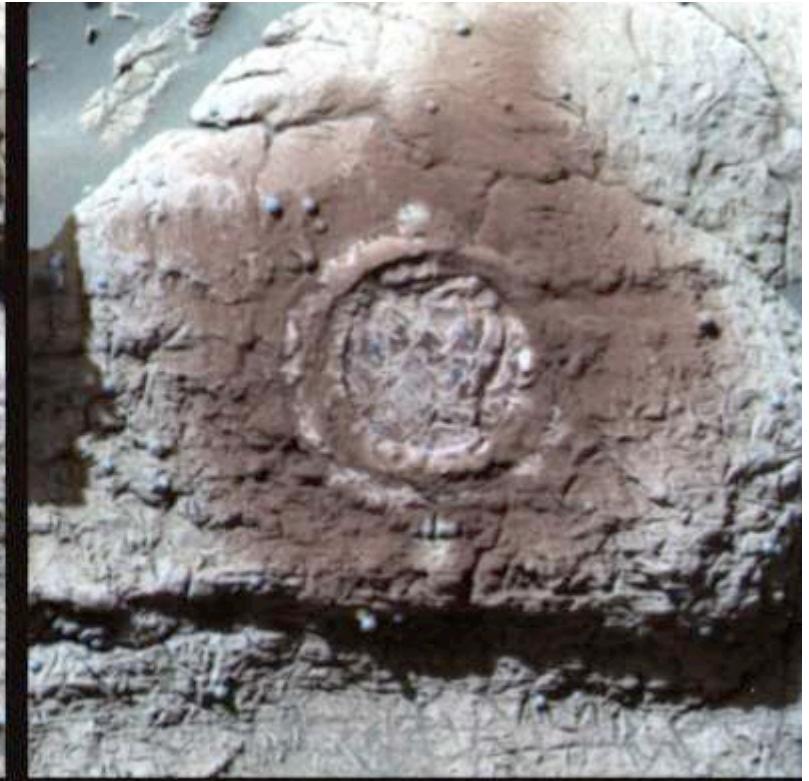
Rock Abrasion Tool (“RAT”)



andis



Sol 27B Pre-RAT, Hole 2



Sol 35B Post-RAT, Hole 2

RAT hole
(before and after grinding)

IDD

Tools on the IDD
“robotic arm”
(view looking down
on the robotic arm in
front of the rover)

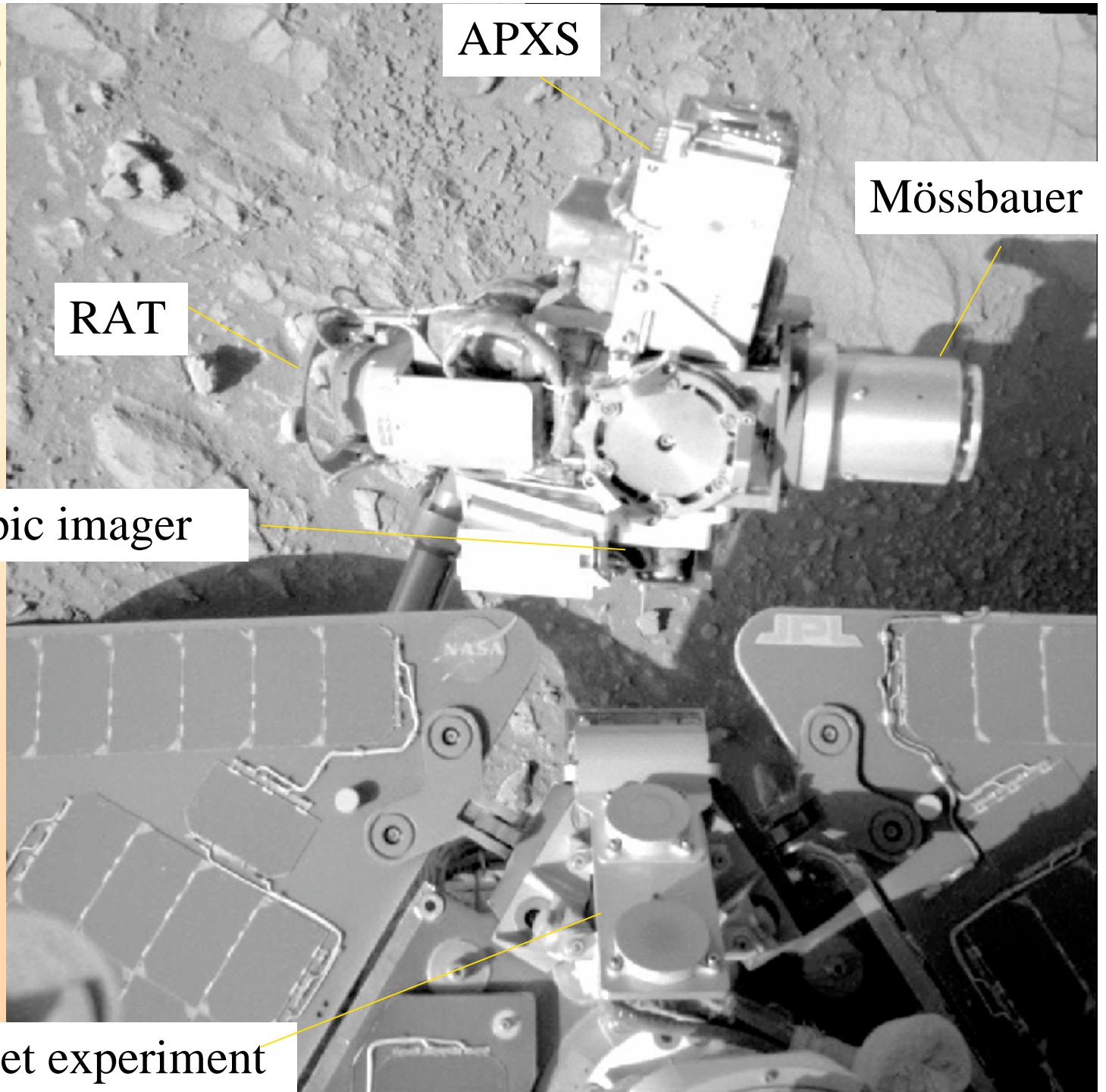
APXS

Mössbauer

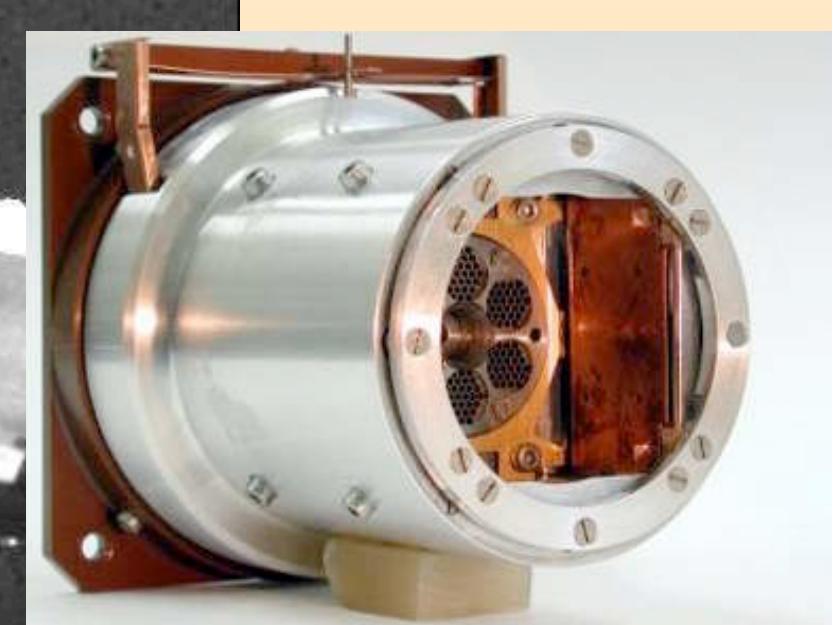
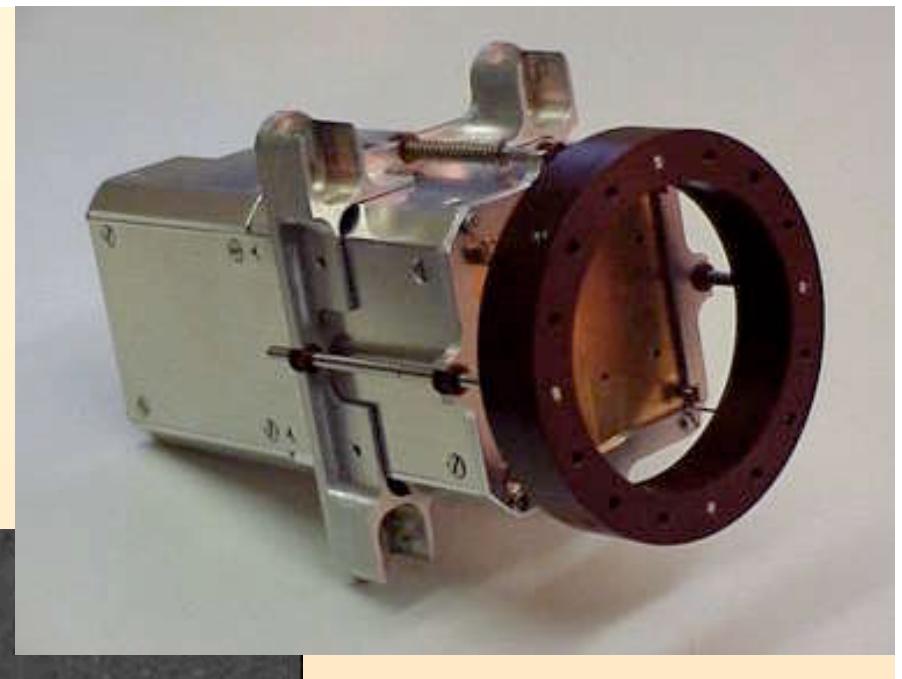
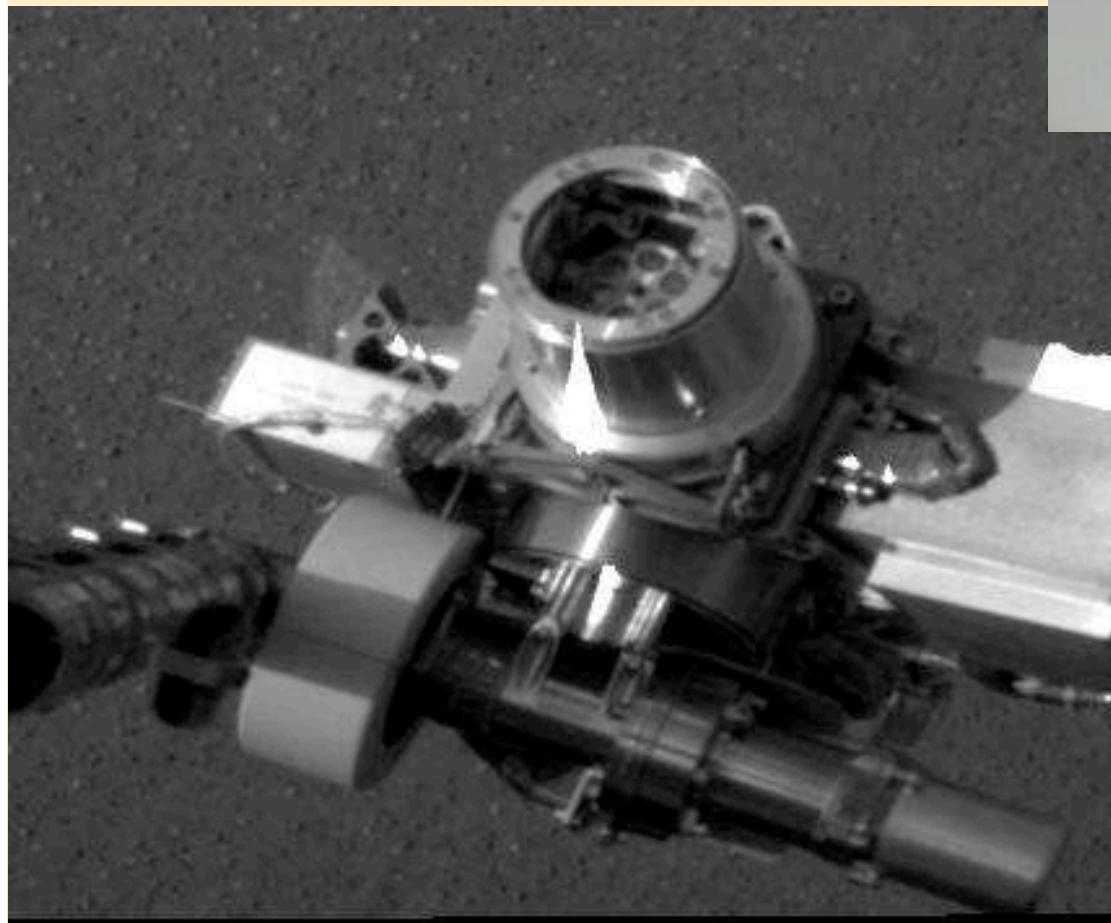
RAT

Microscopic imager

Magnet experiment

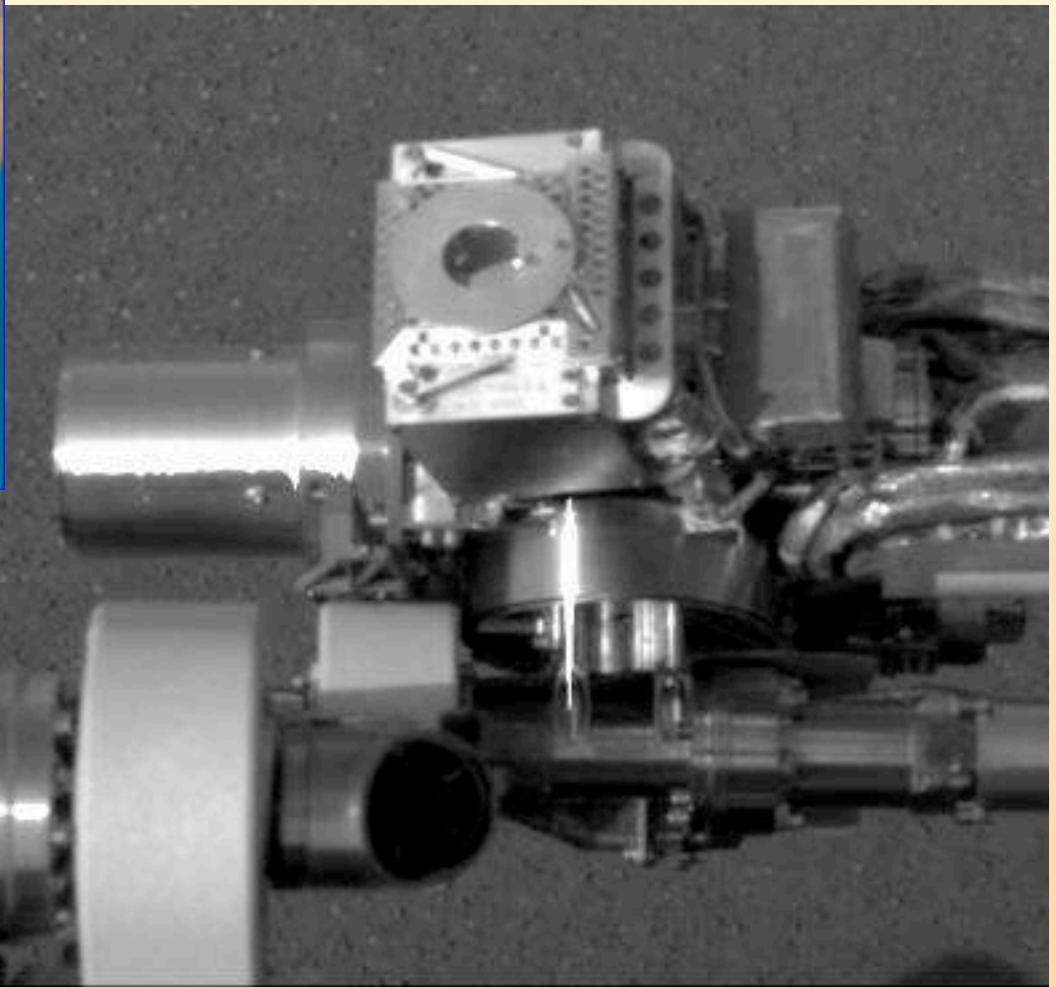
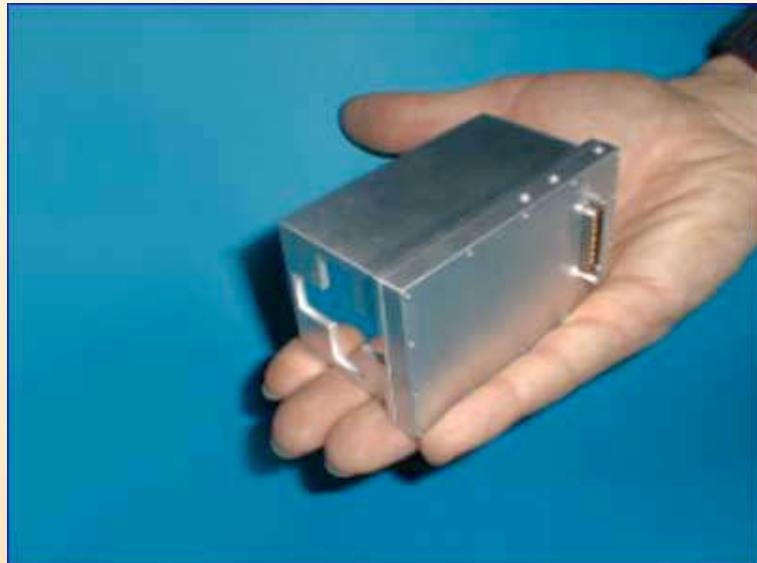


APXS

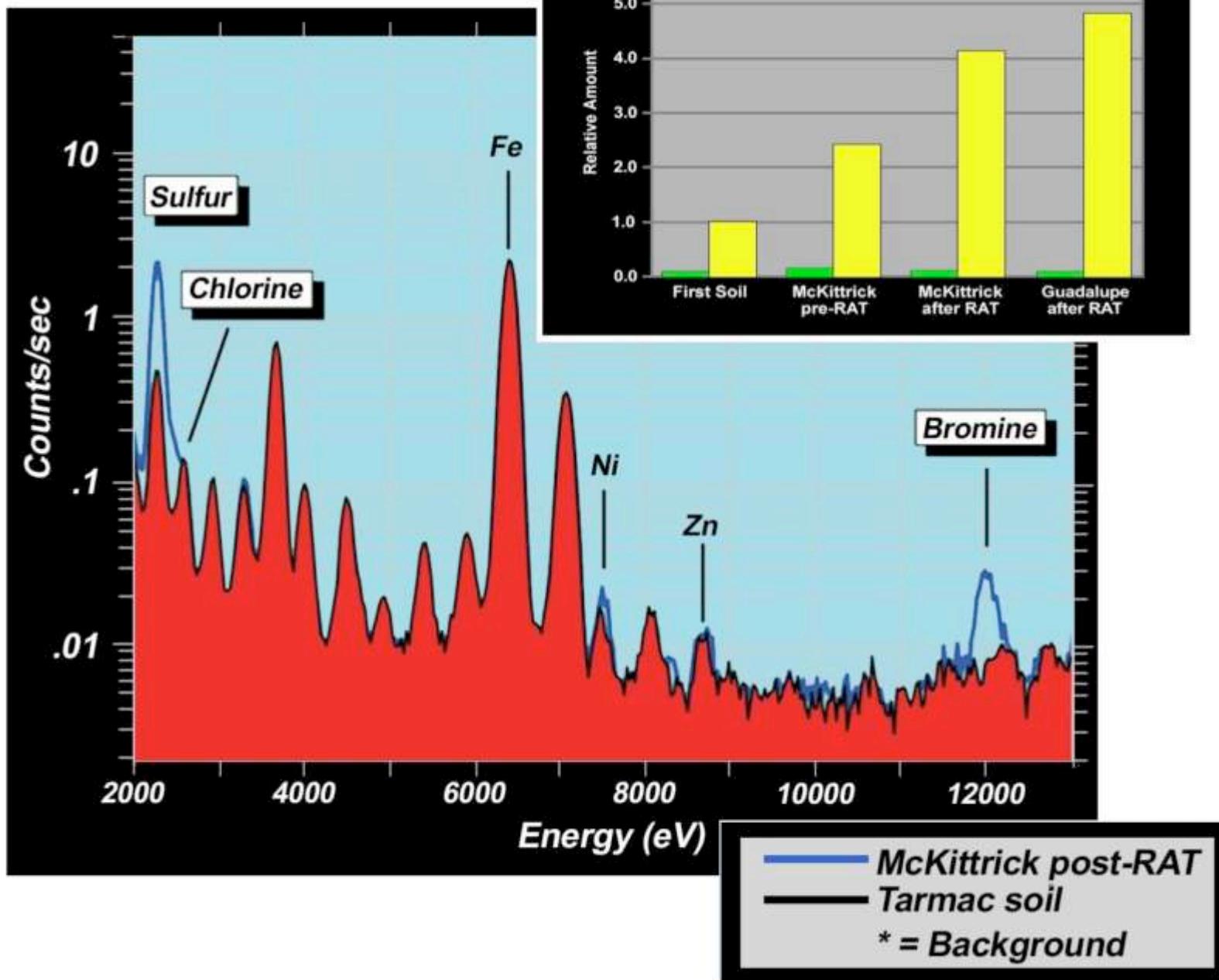


Exploration - Landis

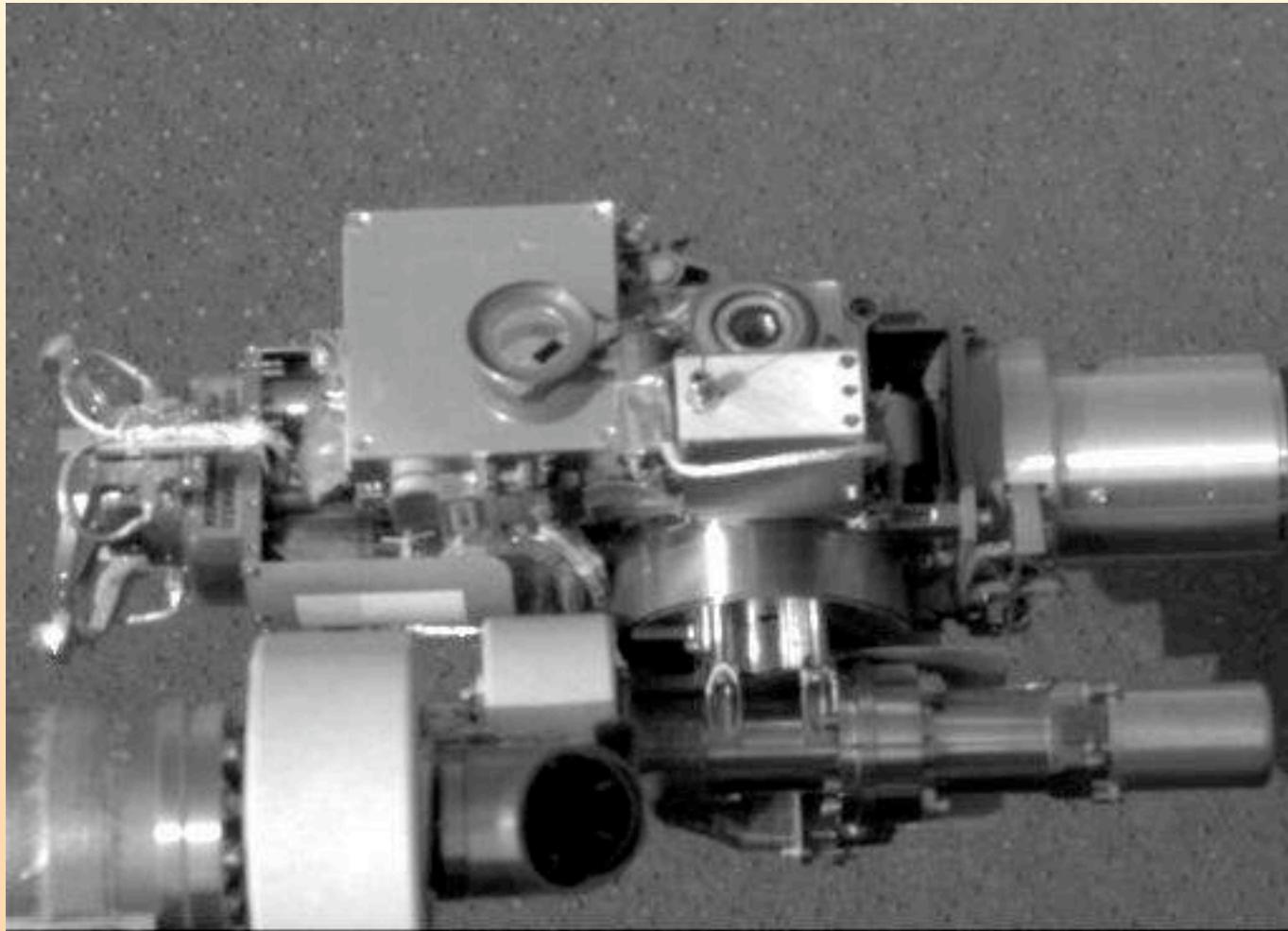
Mössbauer spectrometer



Example APXS results (Opportunity)



Microscopic imager on Mars



Picture from Microscopic
Imager (MI)



Exploration - Landis

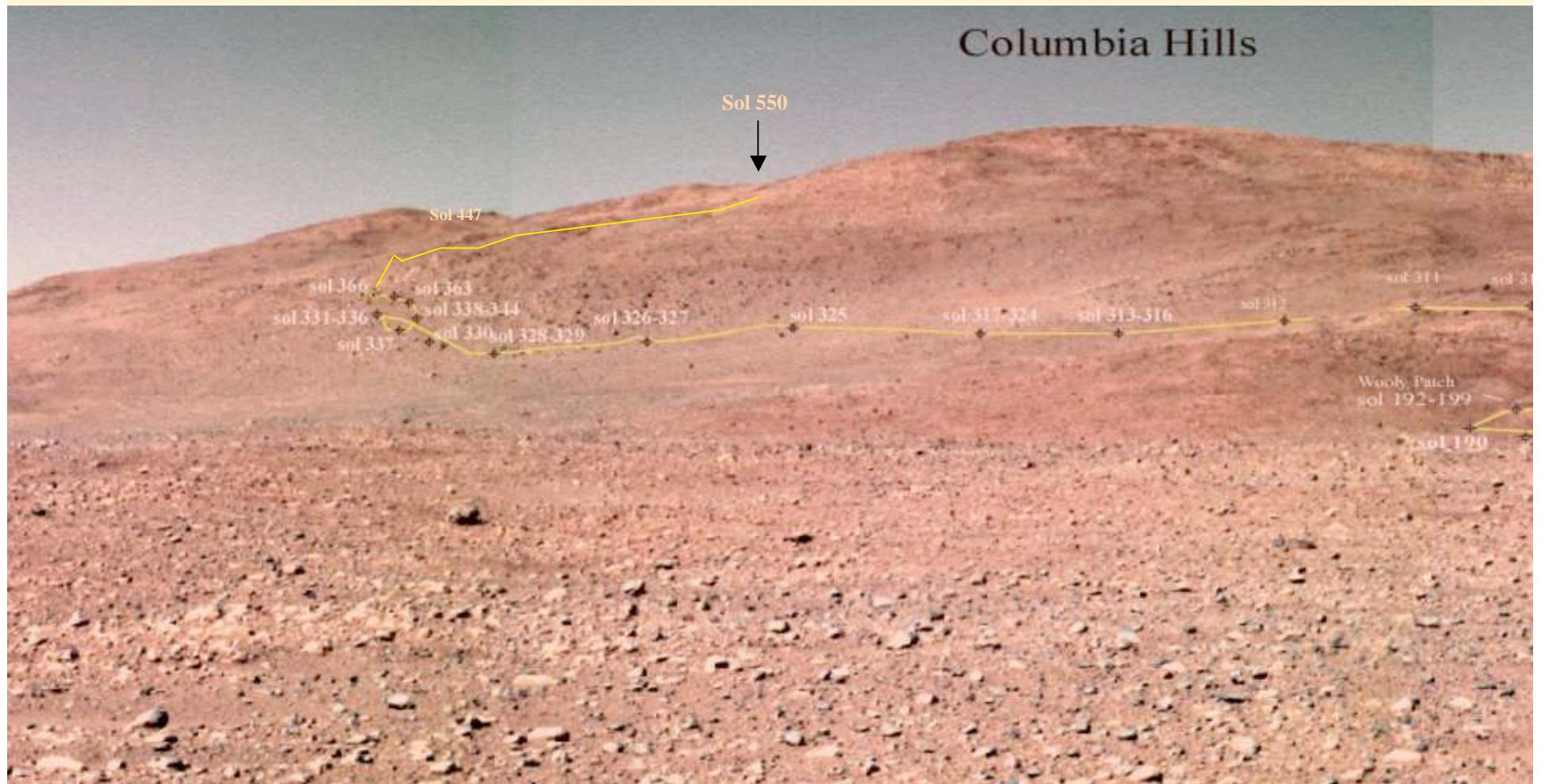
Distant hills....



Spirit: Heading for the hills
(800 meters)



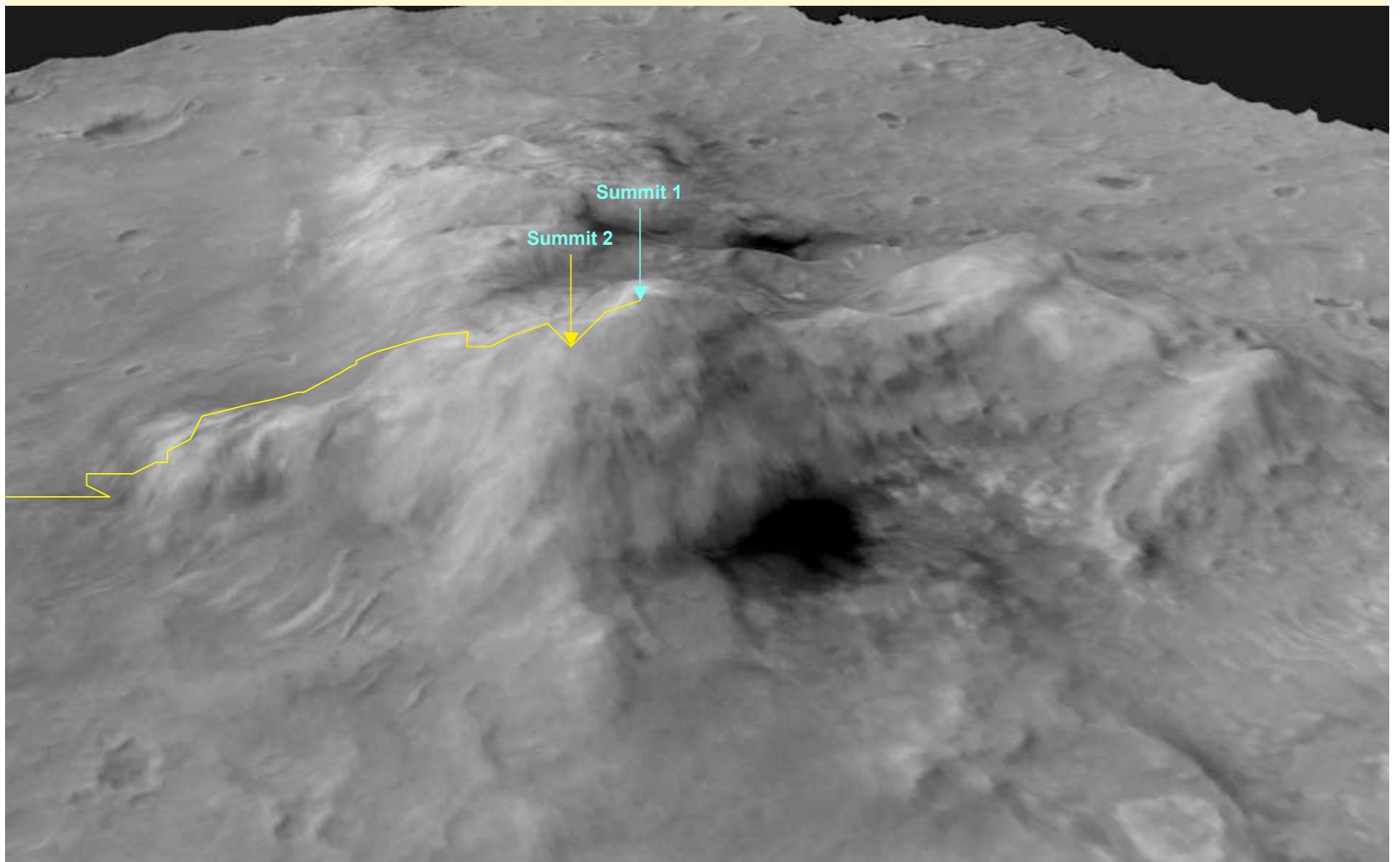
Climbing the hills



(Color is stretched)

Exploration - Landis

Spirit: Climbing Columbia Hills



On the summit

Exploration - Landis

Opportunity's tracks, seen from orbit

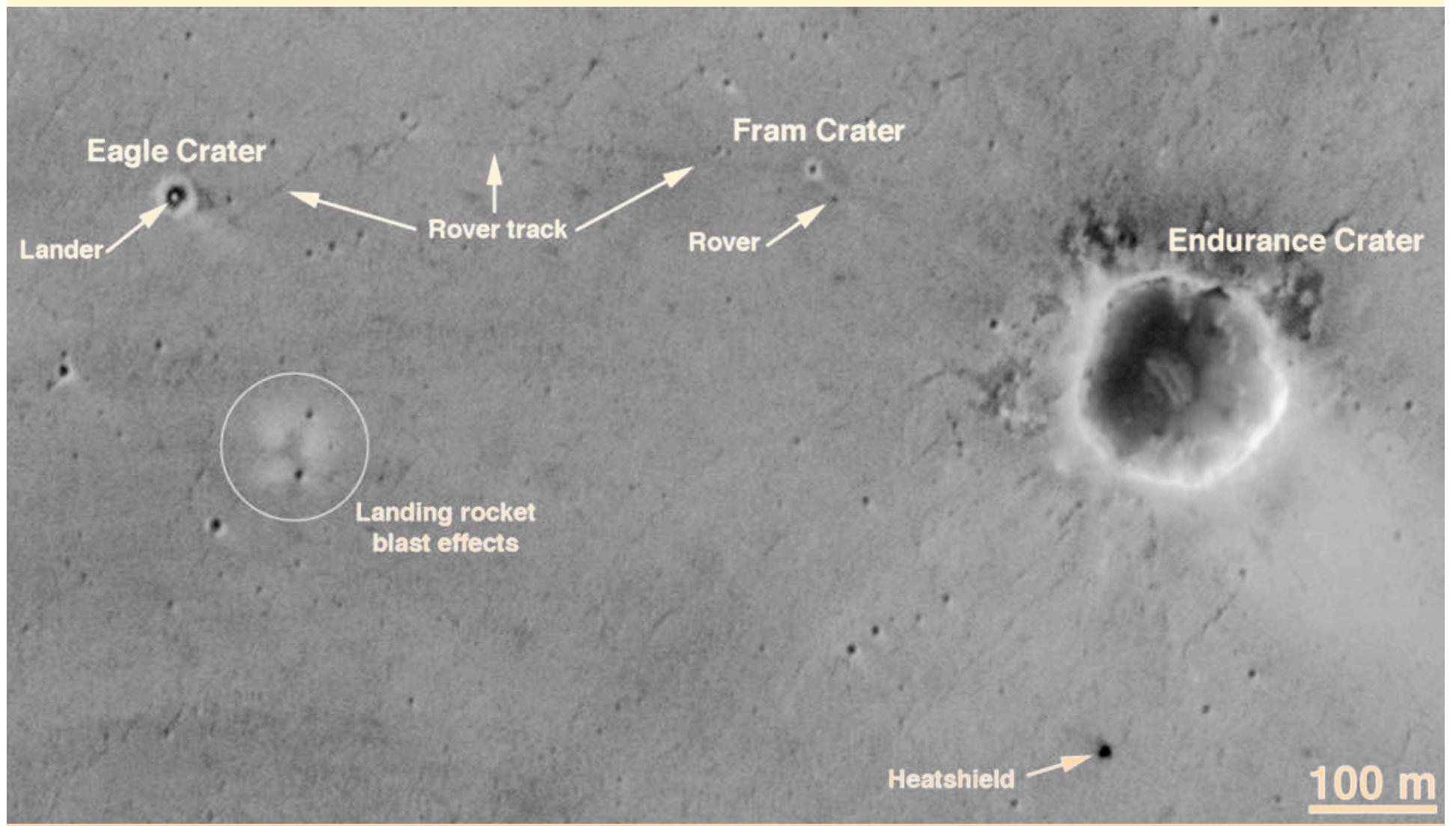


Image from Mars Global Surveyor
courtesy Malin Space Sciences

Exploration - Landis

"Endurance" crater





Landis



Spirit array: getting dusty



View from Pancam looking back across Spirit's solar array

Opportunity- dust loss from Isc cell noon data



Spirit dust cleaning event-- sol 416

Sol 416A



Sol 417A



Uncalibrated color images

Dust devil in motion



Spirit, Sol 459 (20 seconds between frames)

Close Dust devil



0162

Time
in seconds

Spirit, Sol 456 (20 seconds between frames)

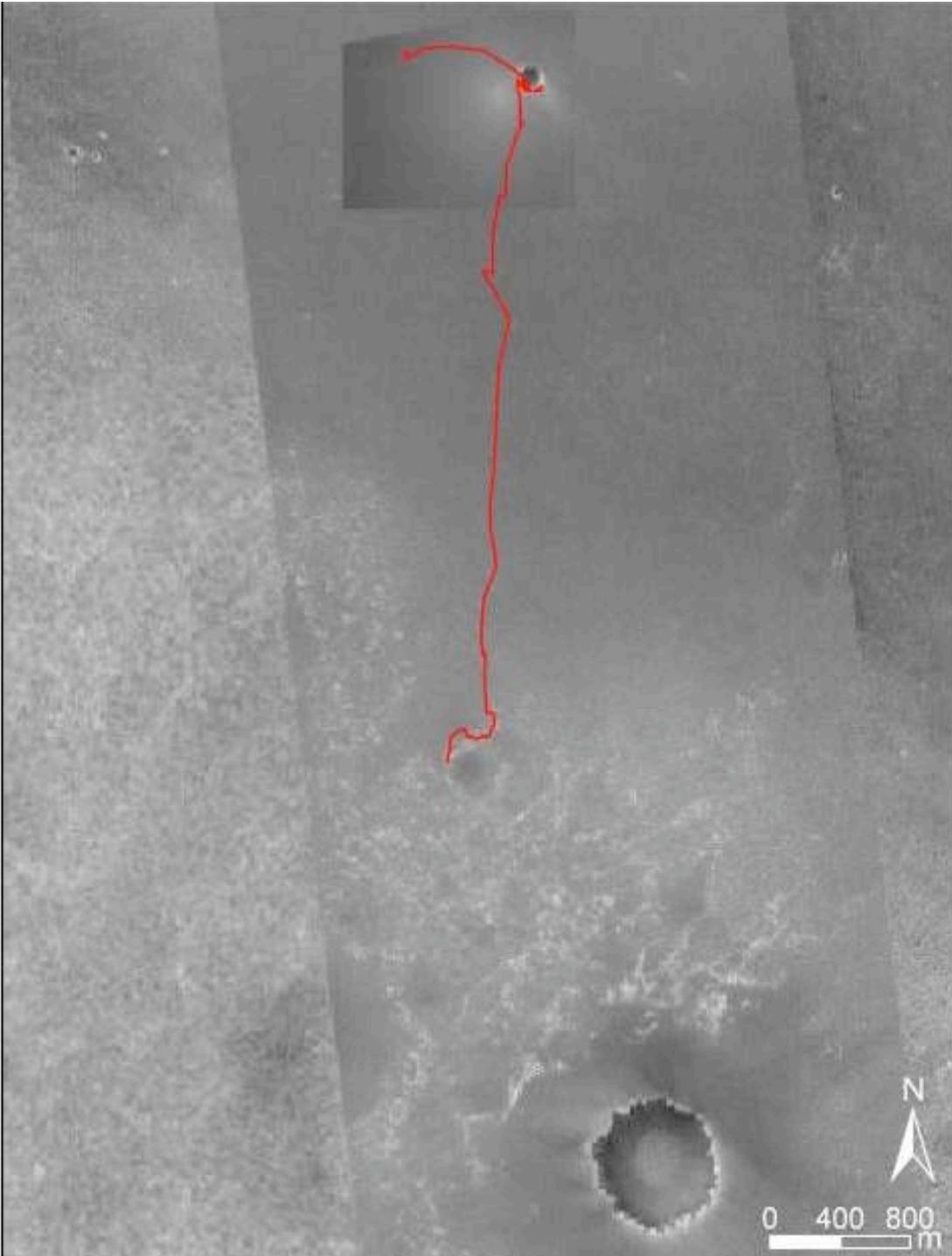
Lots and Lots of Devils!



0000

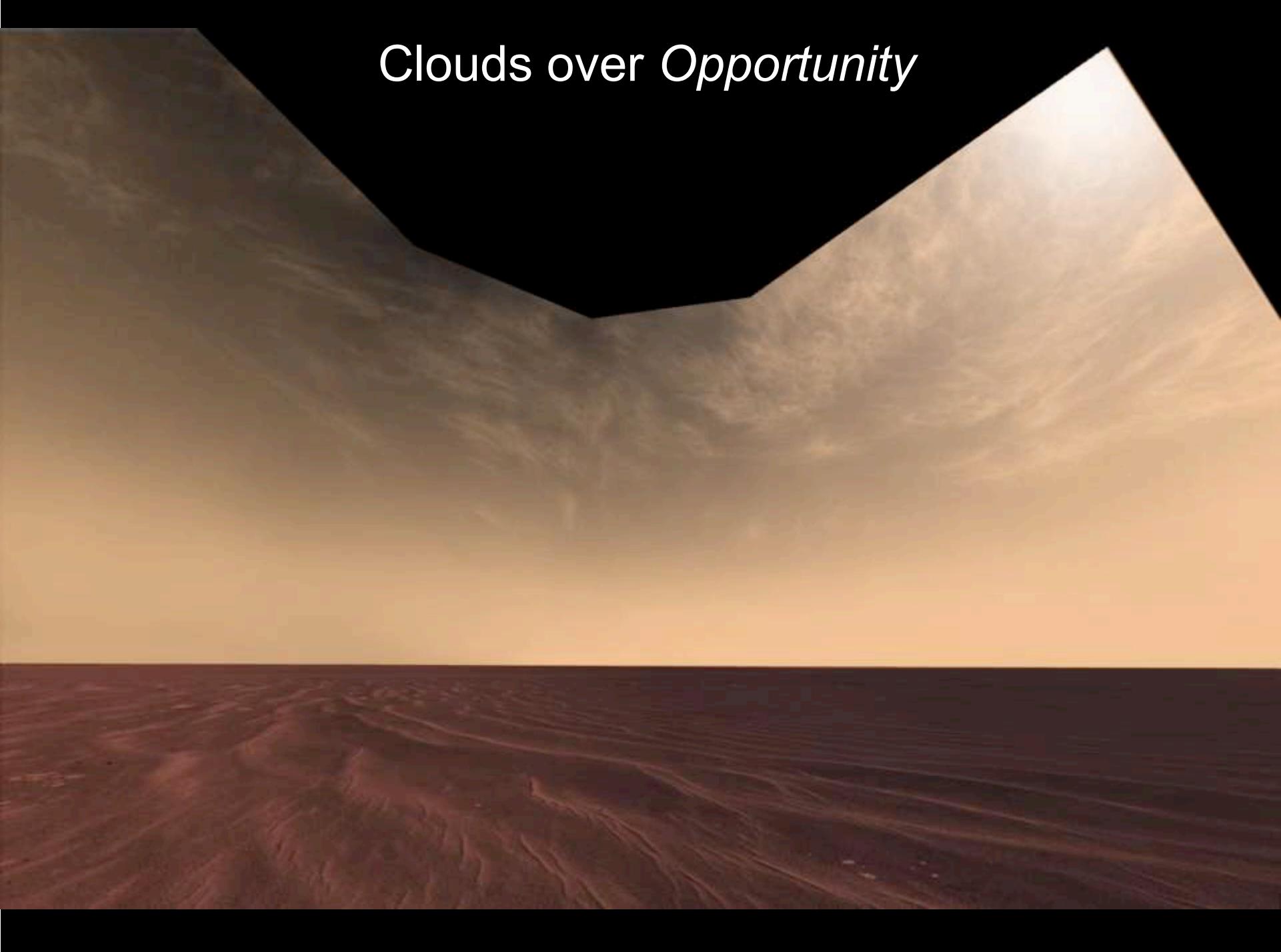
Sol 568(20 seconds between frames)

Motion enhanced



Traverse toward "Victoria"

Exploration - Landis



Clouds over Opportunity

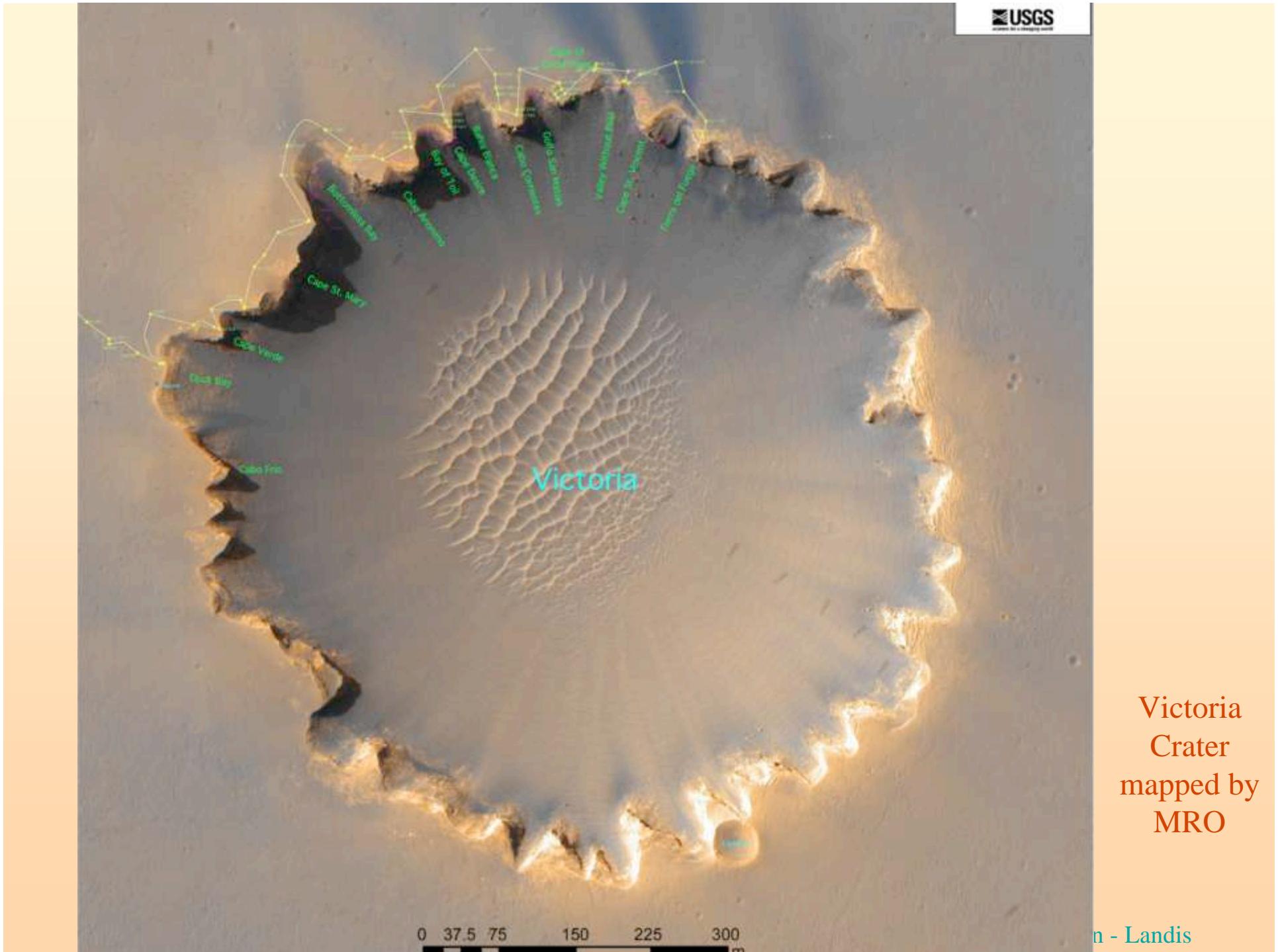
Bitty Cloud, the Movie (B 956)



Earthrise, sol 682



Exploration - Landis



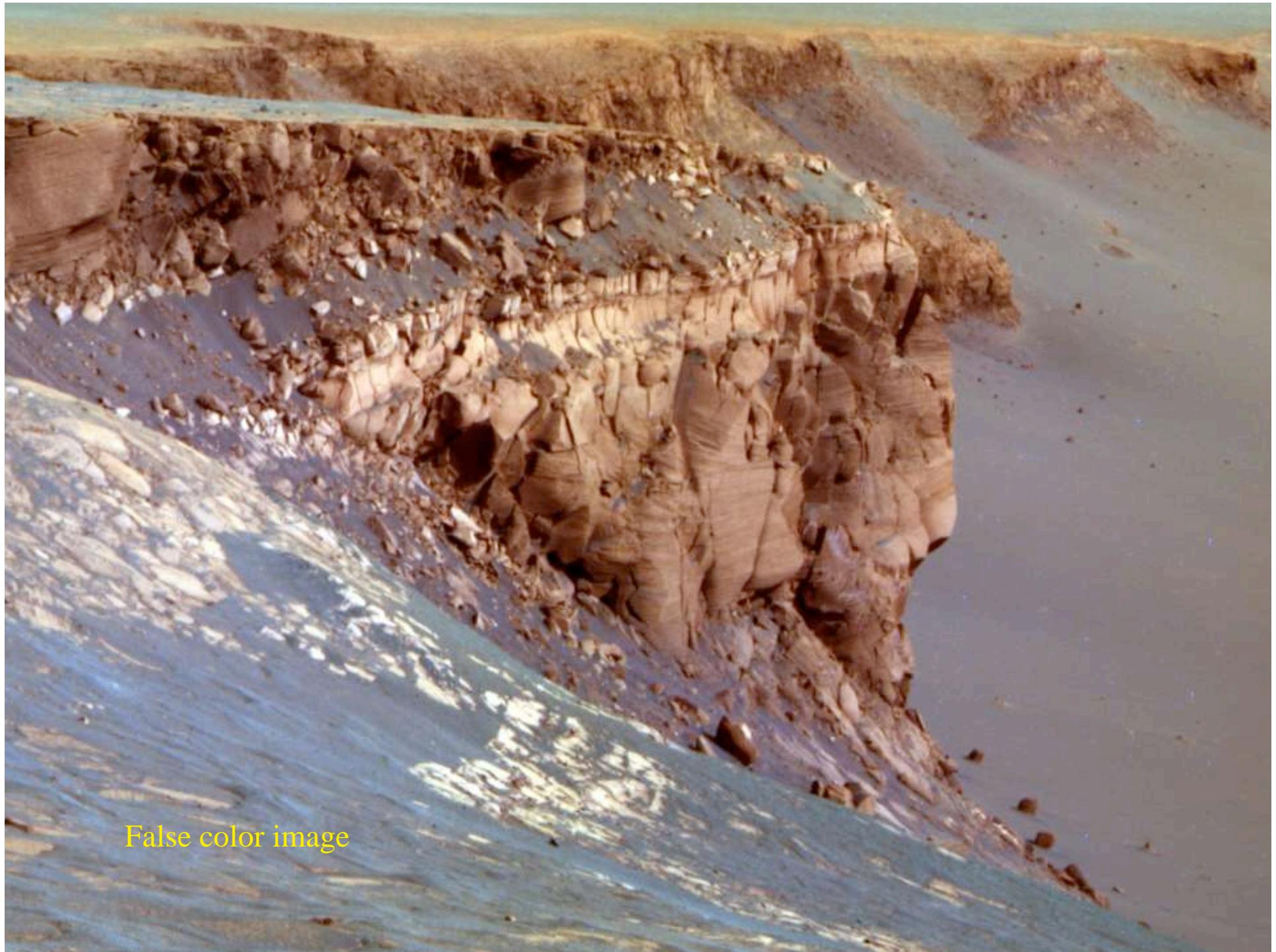
Victoria Crater mapped by MRO



Exploration - Landis

Opportunity Rover viewed from
MRO





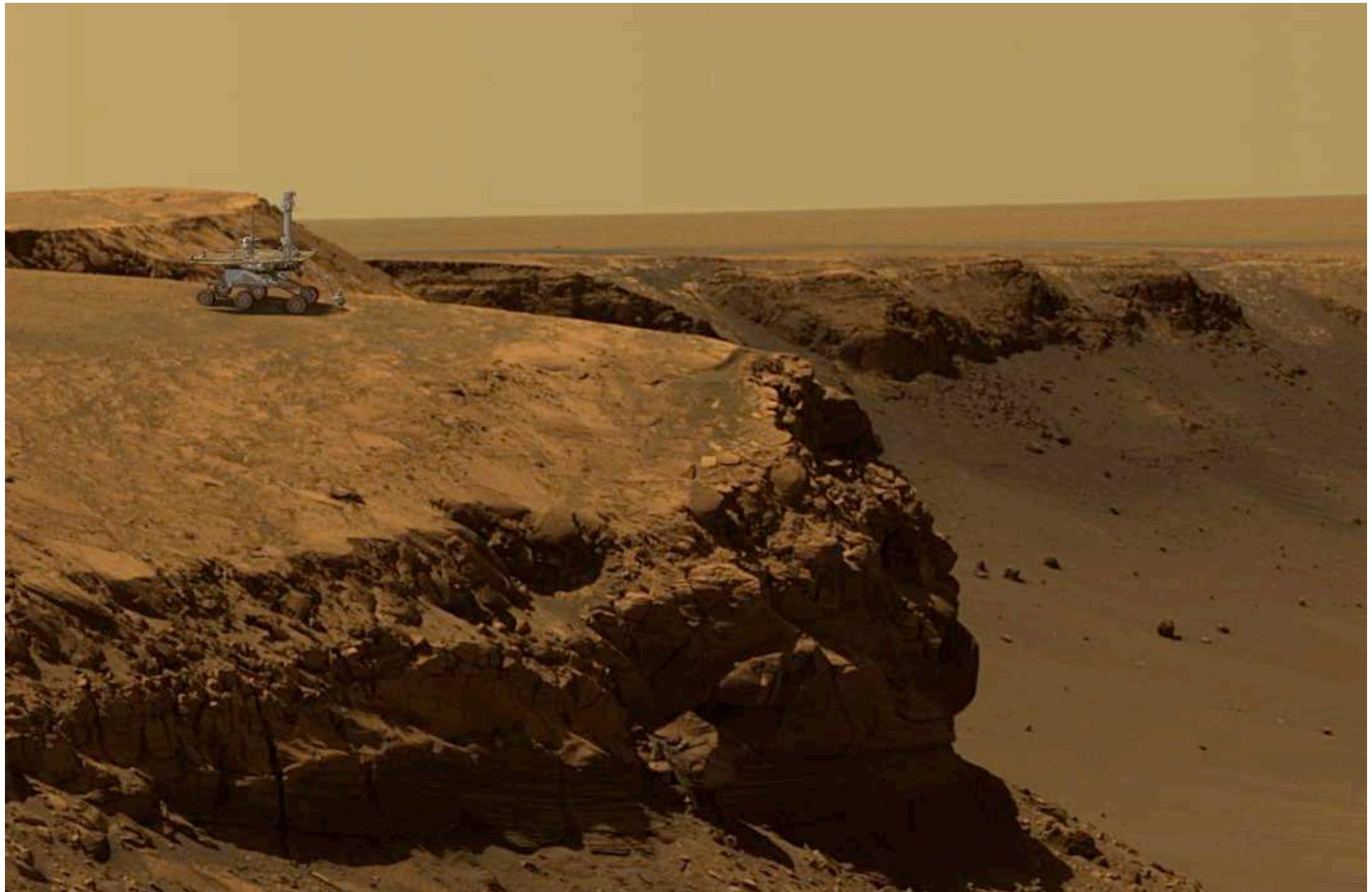
False color image

"Good Hope" close up in
stretched color



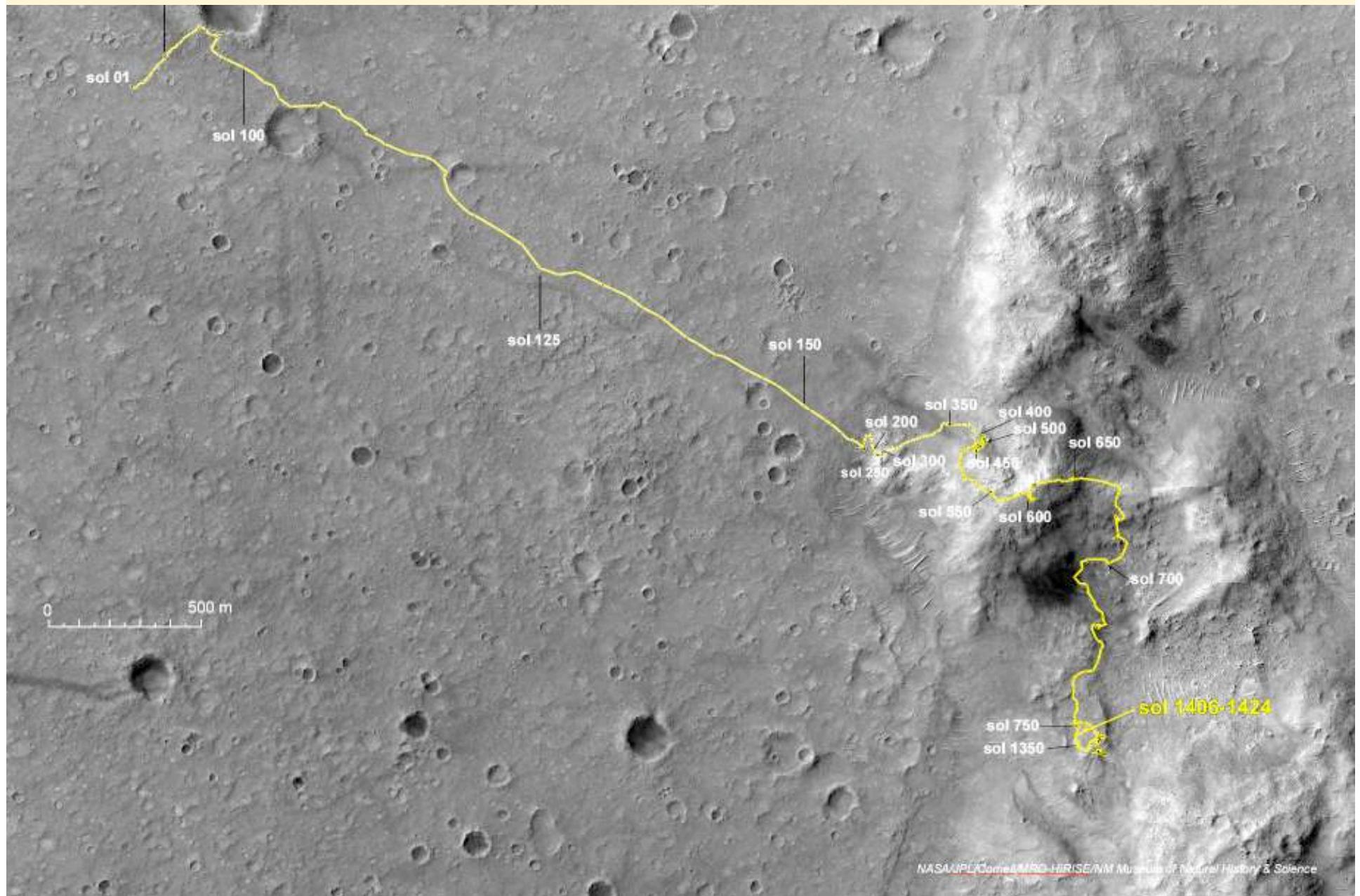


Cabo Corrientes in false color



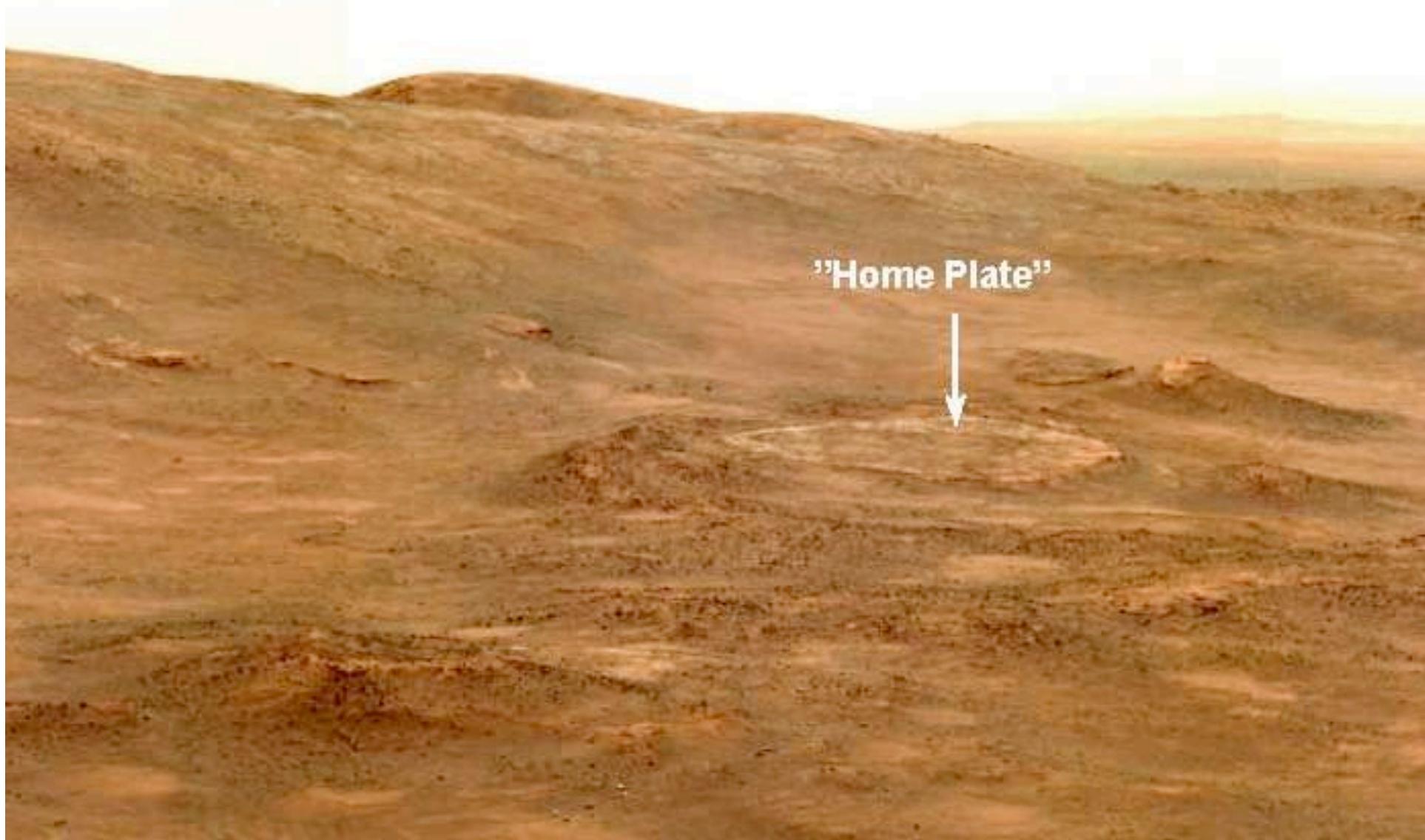
Relative size of Opportunity if it could be viewed at Duck Bay
(pancam true color) **with a little help from Photoshop**
Exploration - Landis

MER A traverse map



NASA/JPL-Caltech/IMA-HRSC/Museum of Natural History & Science

Home plate



"Home Plate"

View from home plate





Home plate
(true color)

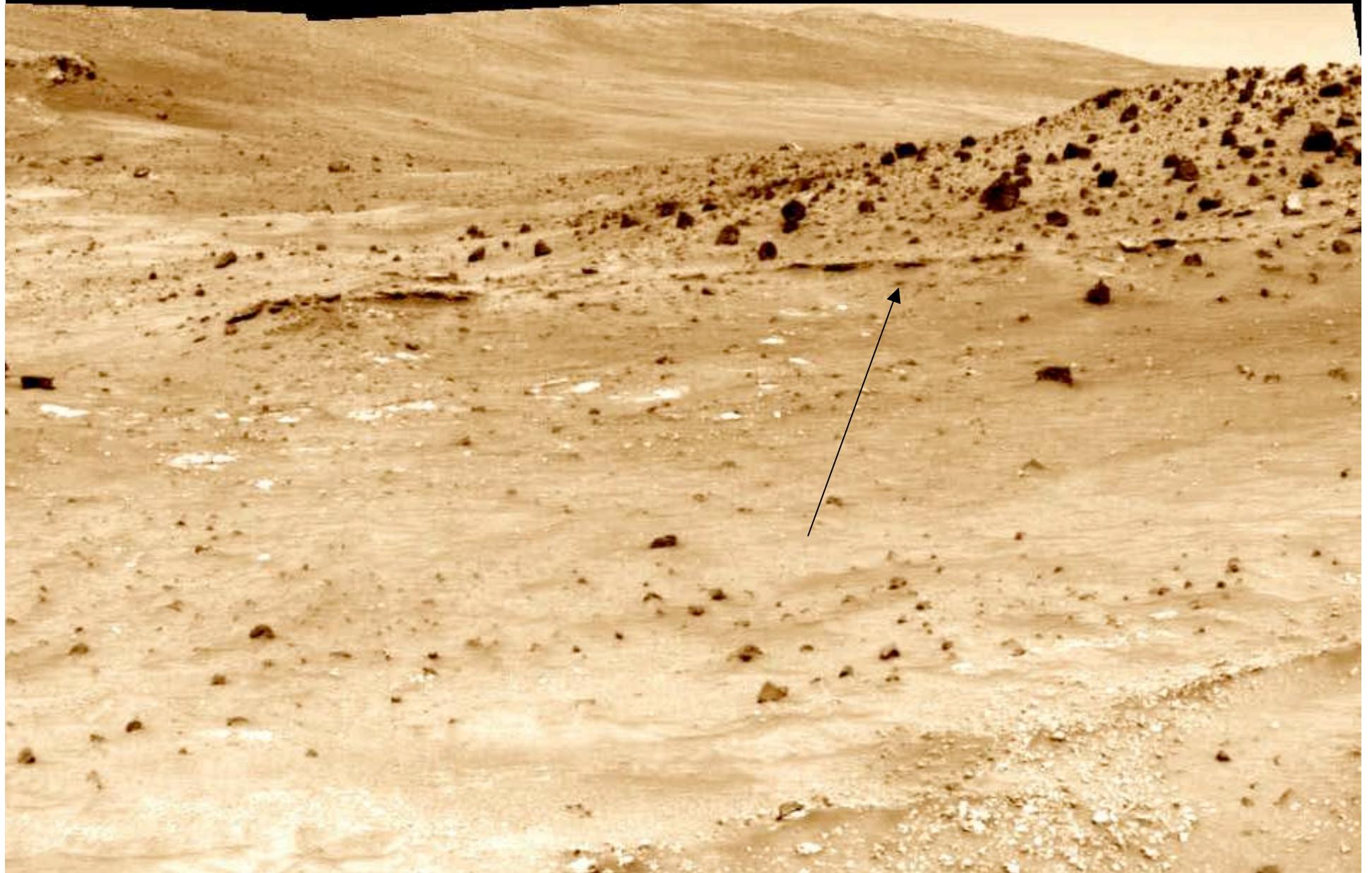


Home plate: "bomb sag" (false color)



Skid marks and white salt
under the soil

Spirit Winter haven 2006: Sol 810-811



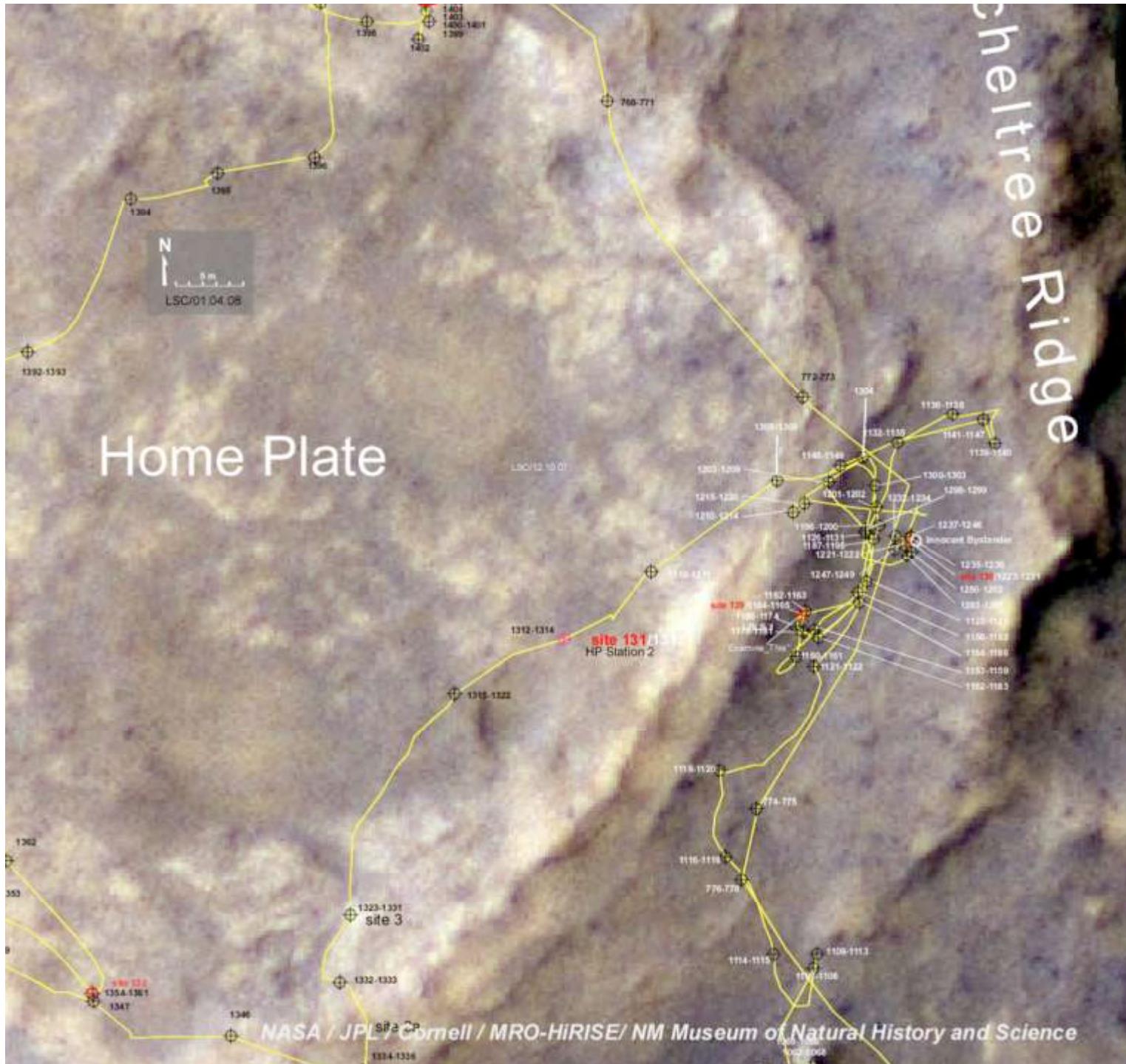
Spring on Mars: Dust devil season returns



Sol 1120 A

(Motion enhanced)

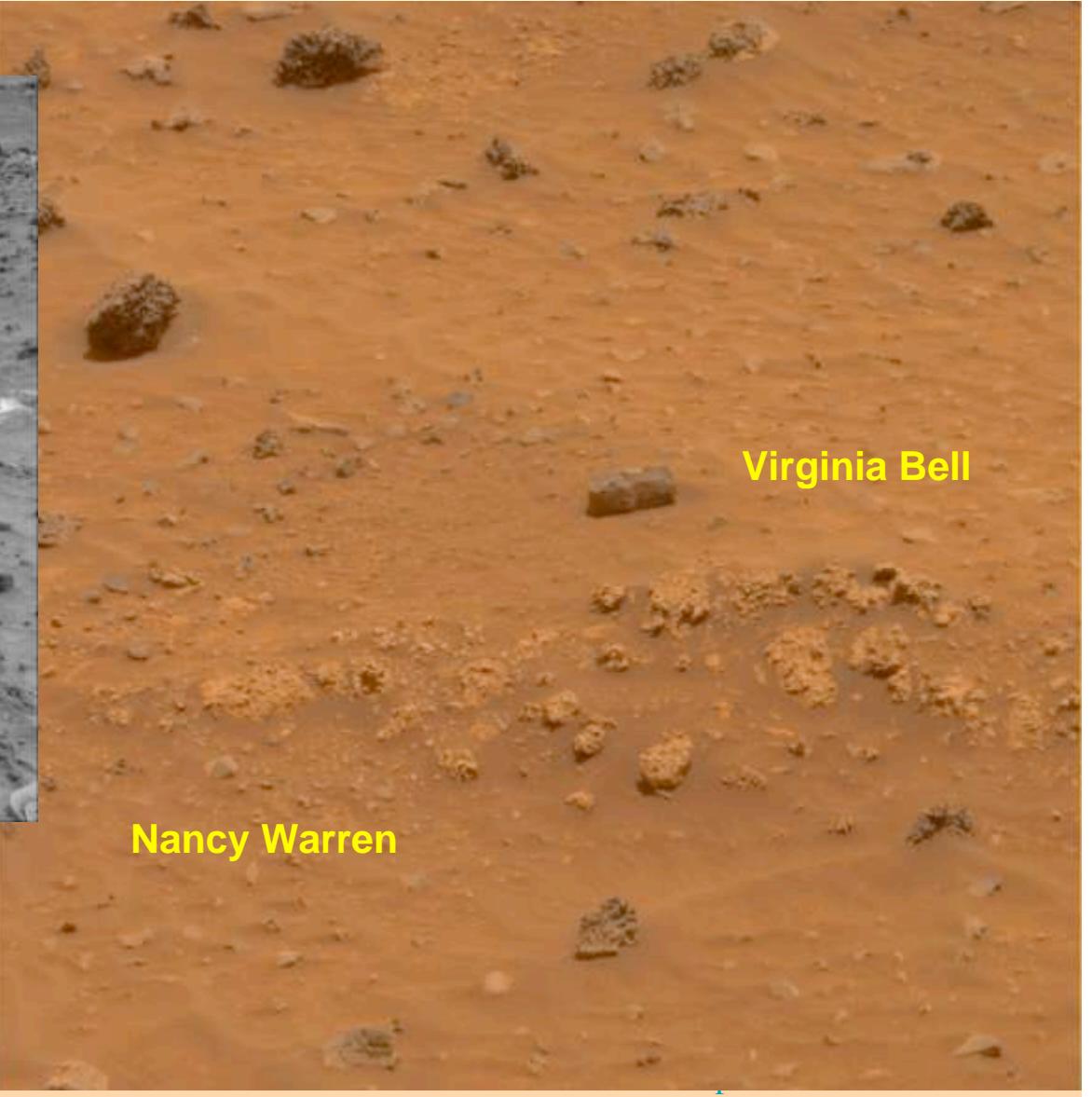
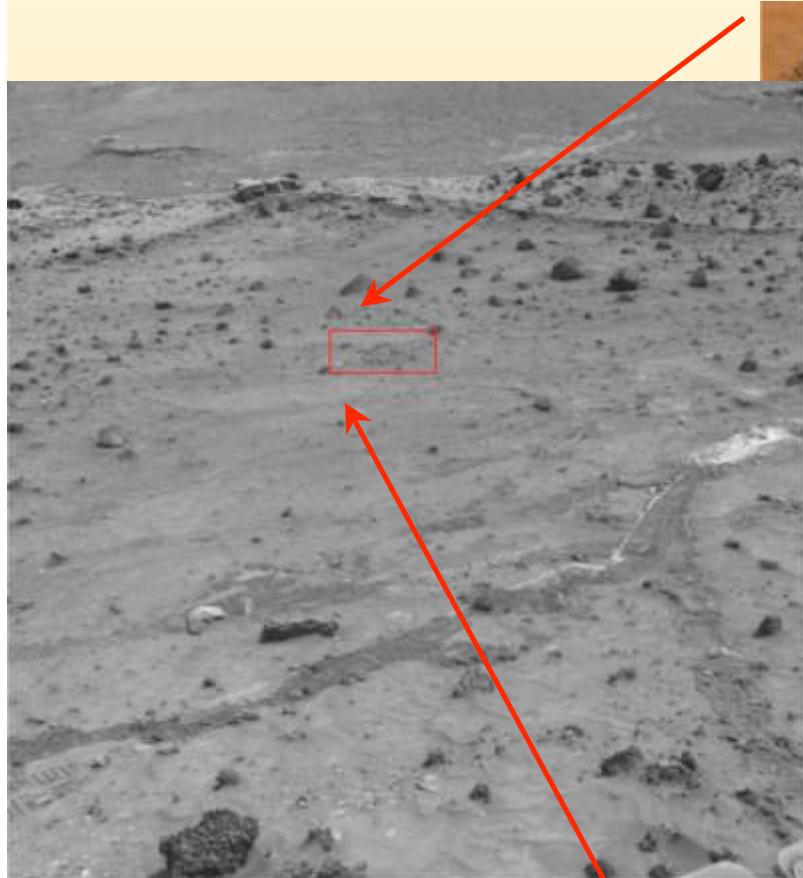
Exploration - Landis



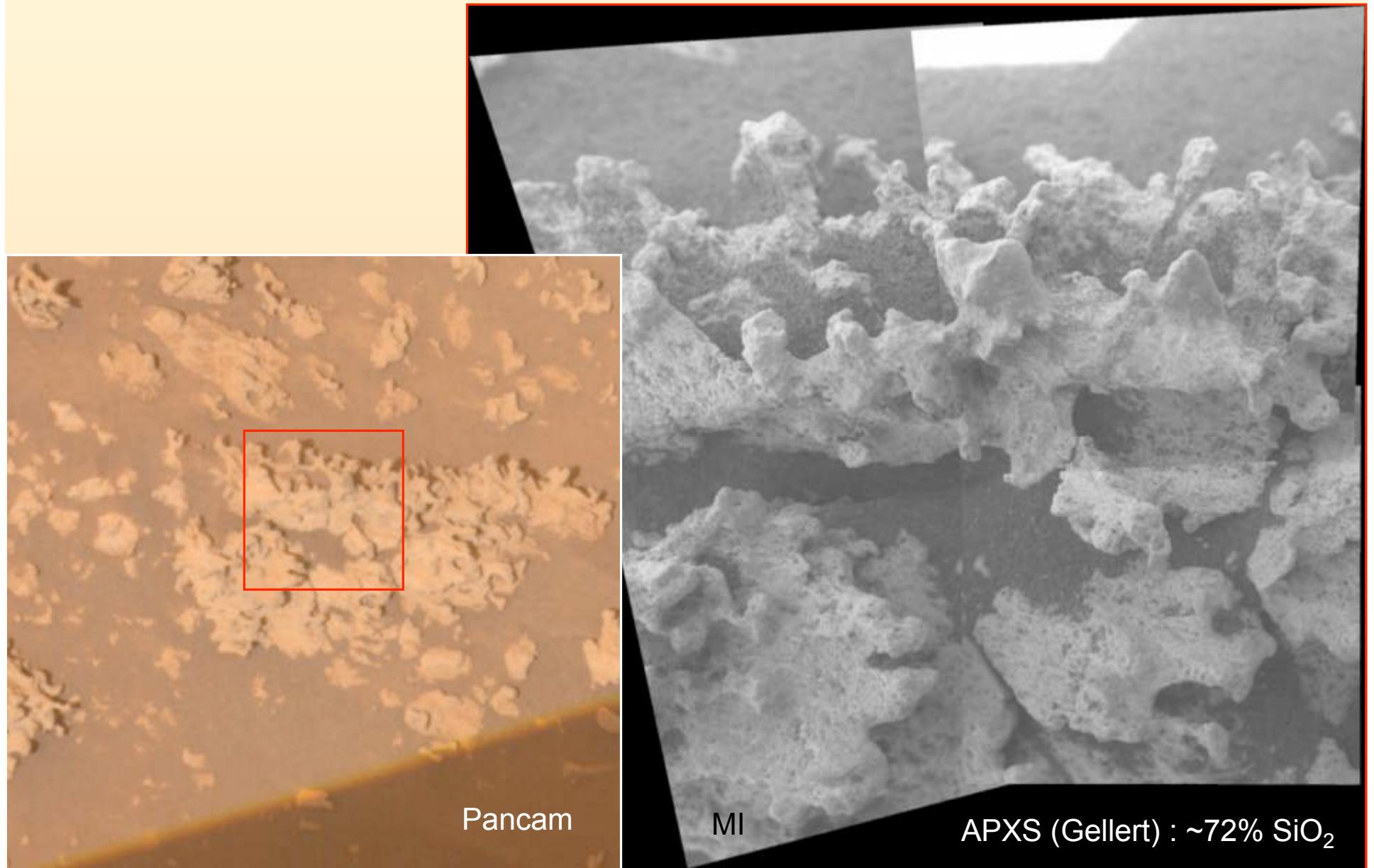
East of Home Plate: "Silica Valley"

High Silica Nodular Outcrops

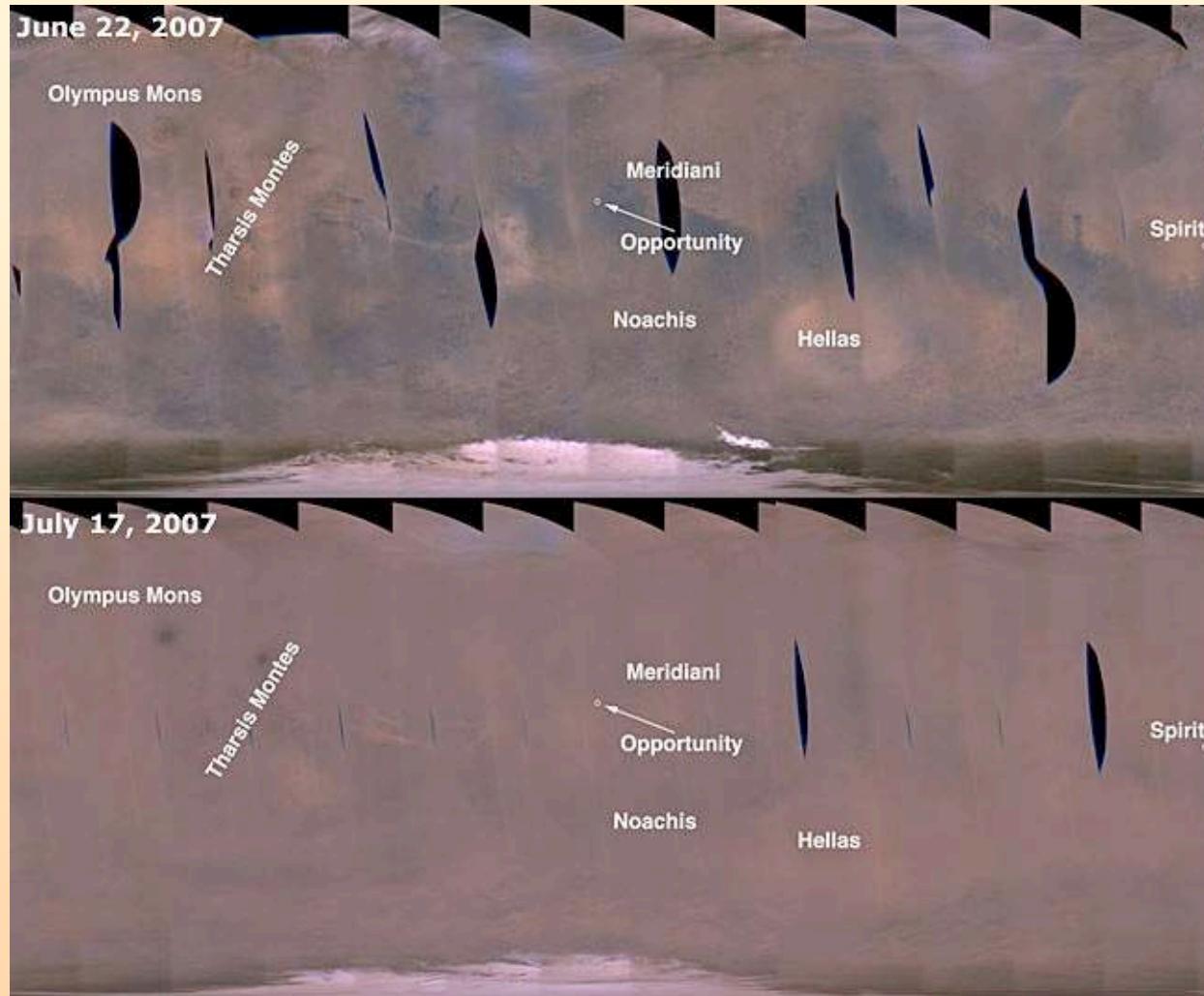
Highest silica percentage found (from APXS):
Soil target "Gertrude Weise": ~90% SiO₂



Silica: Fumerolic alteration?
Signature of hot springs



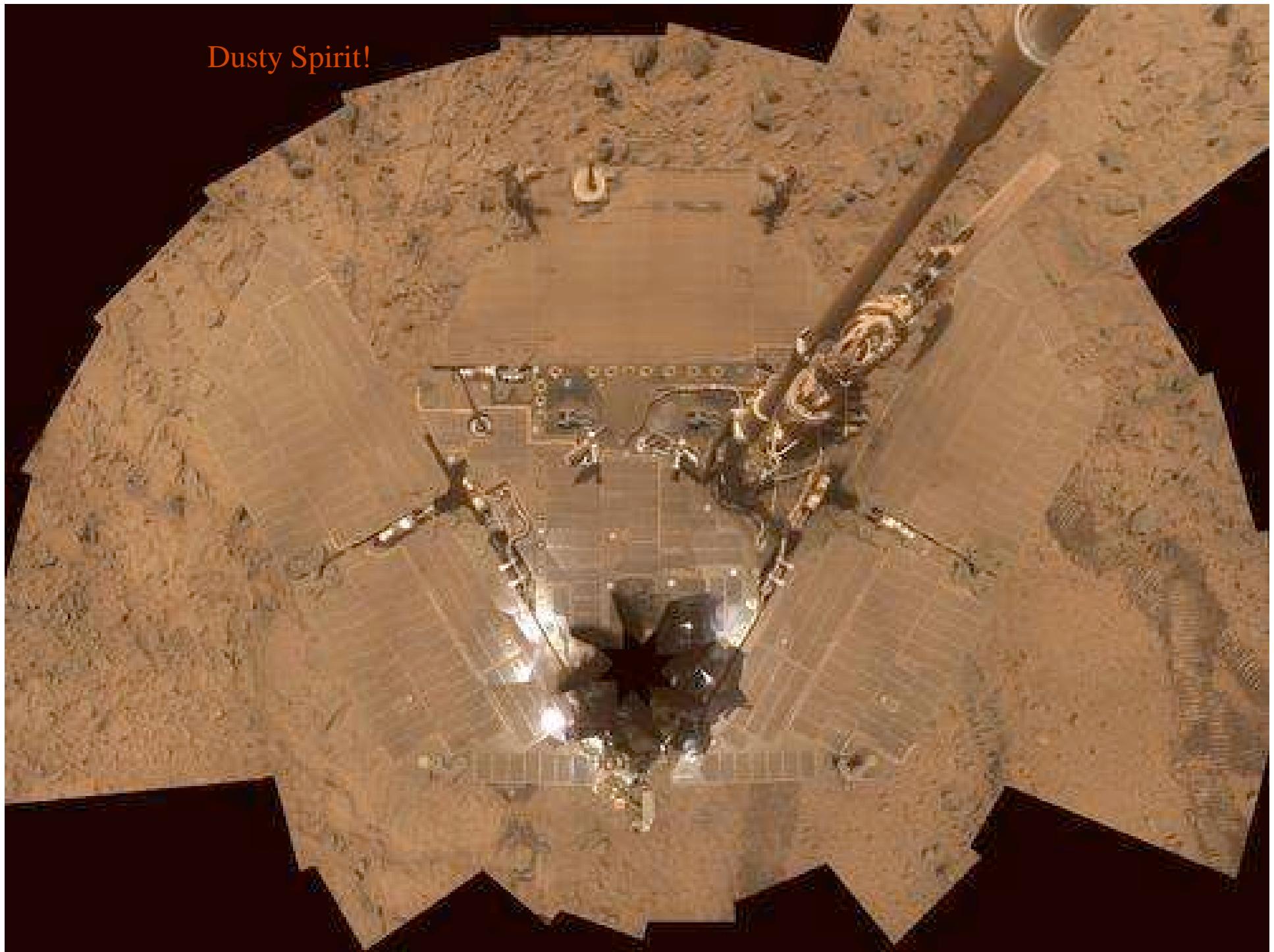
Mars Reconnaissance Orbiter views Dust from Orbit note loss of surface features due to dust storm!



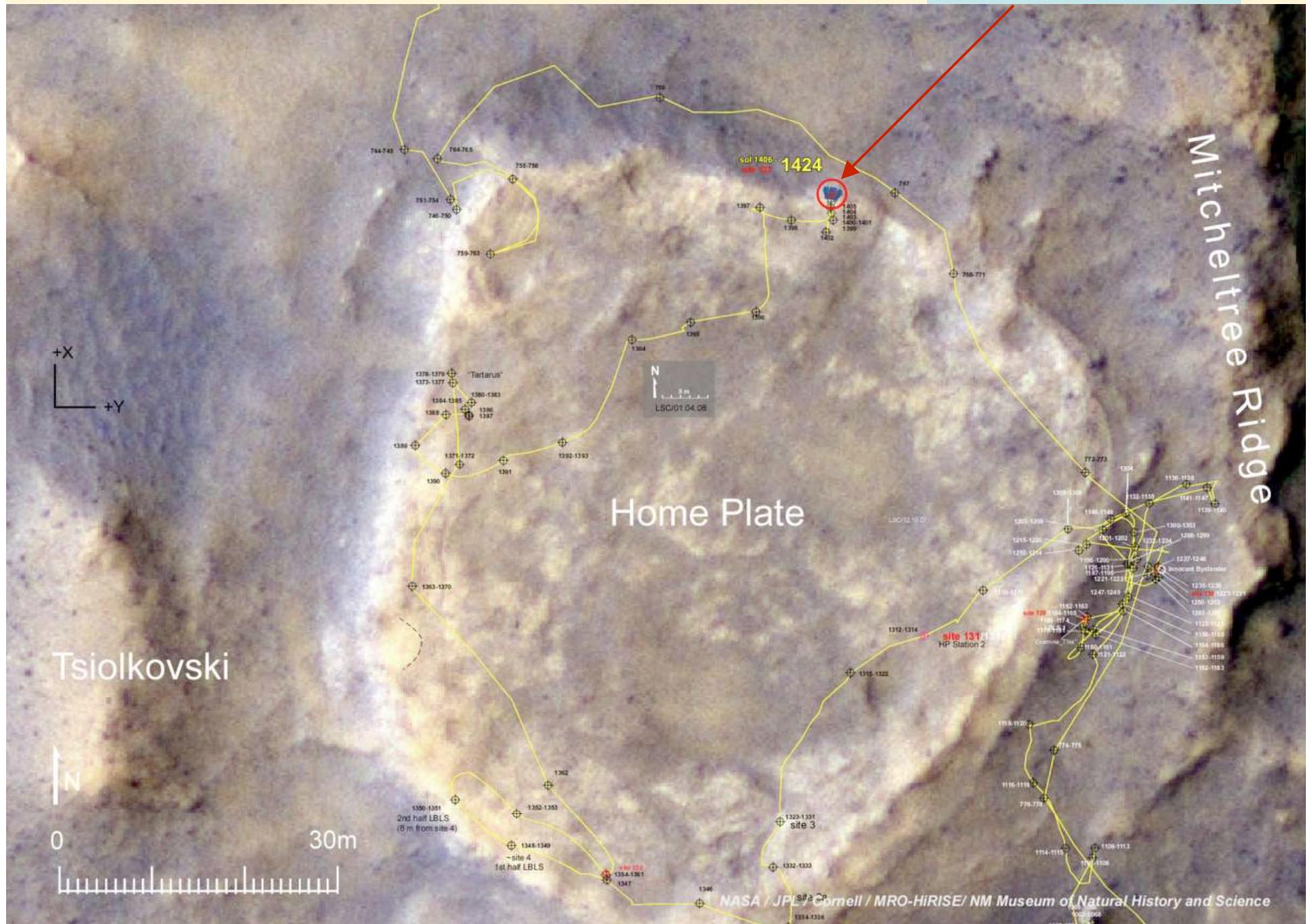
Dust storms



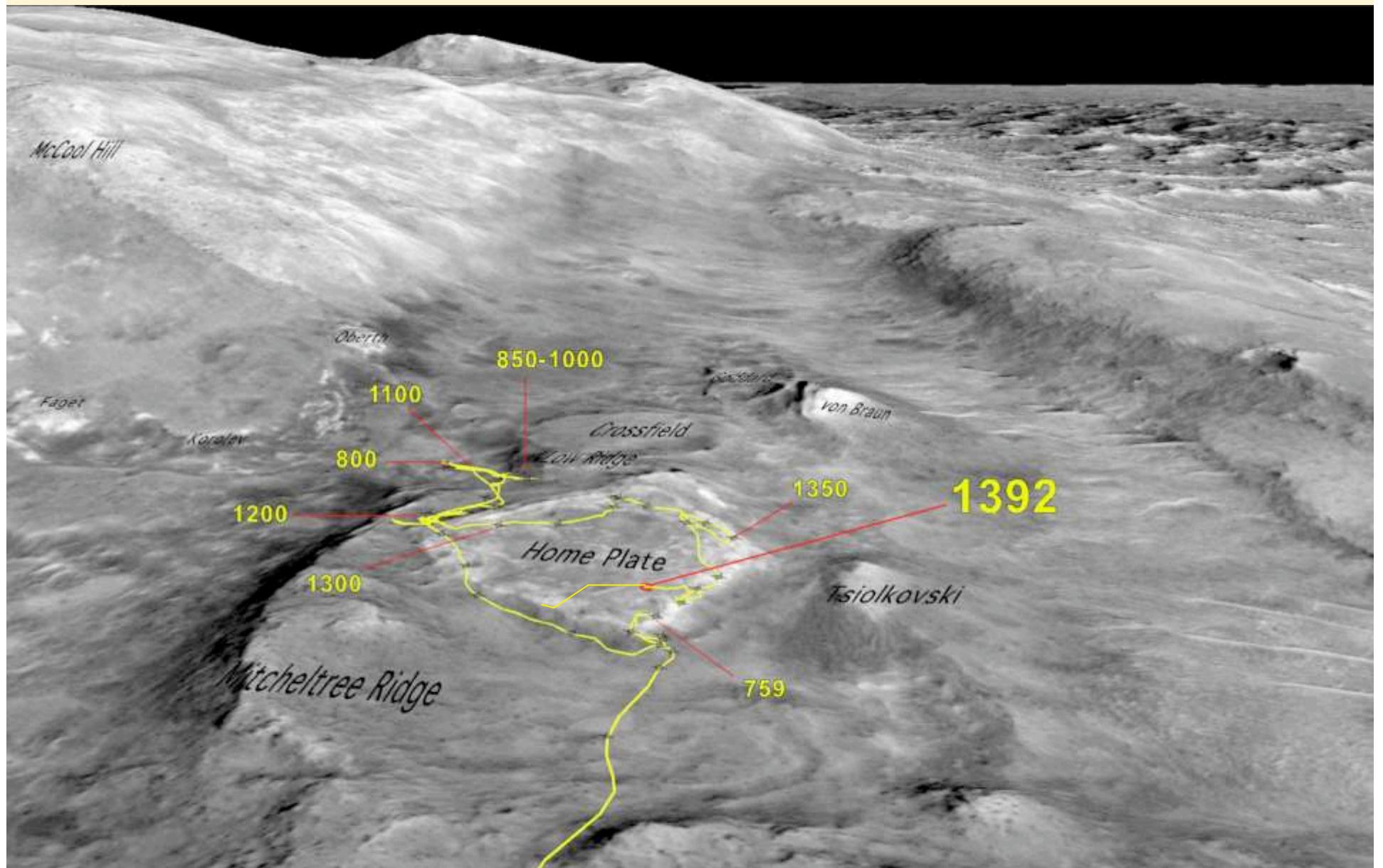
Dusty Spirit!



Where we are today



Winter haven at north edge of
home plate

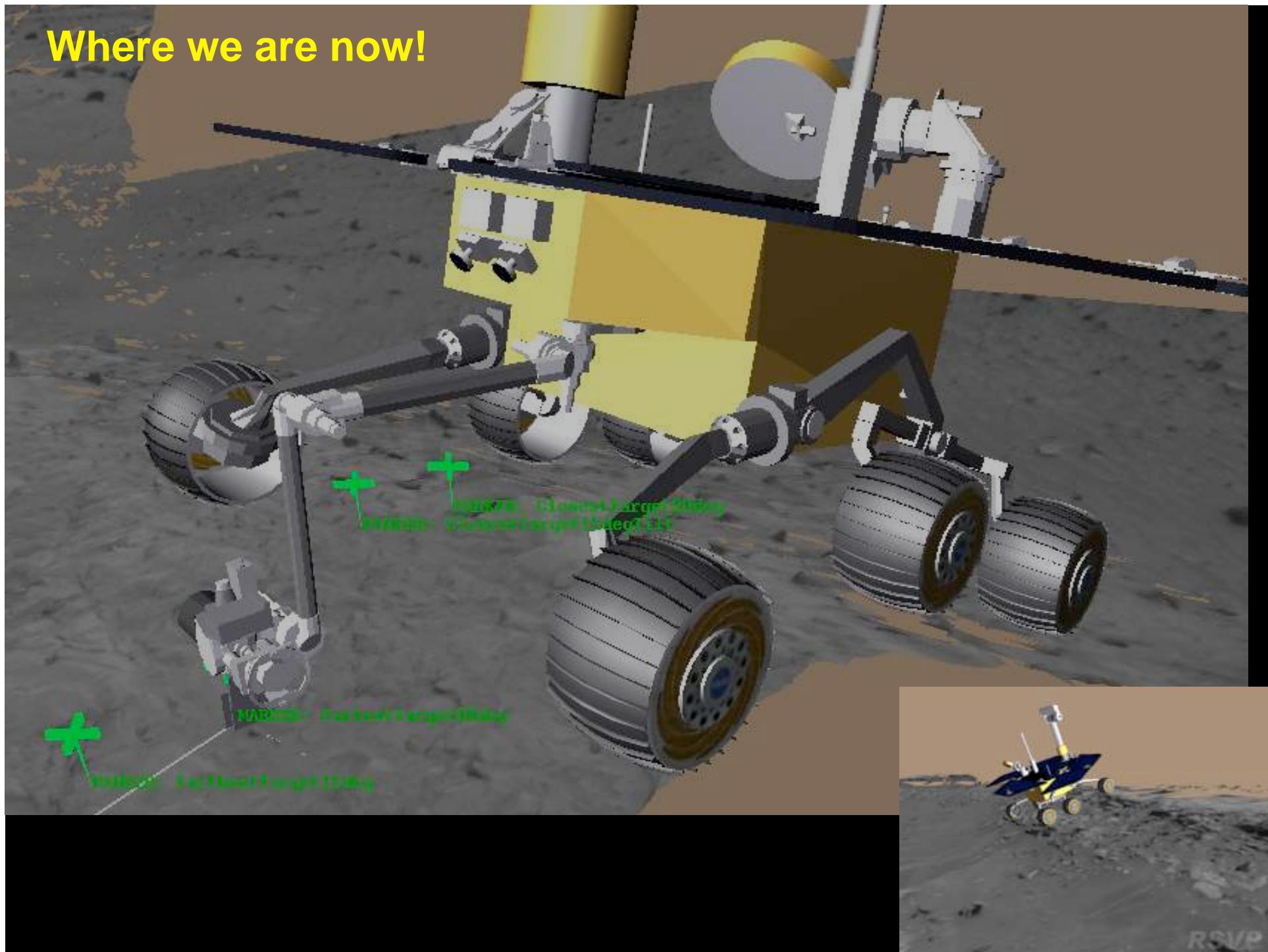


View from our winter haven



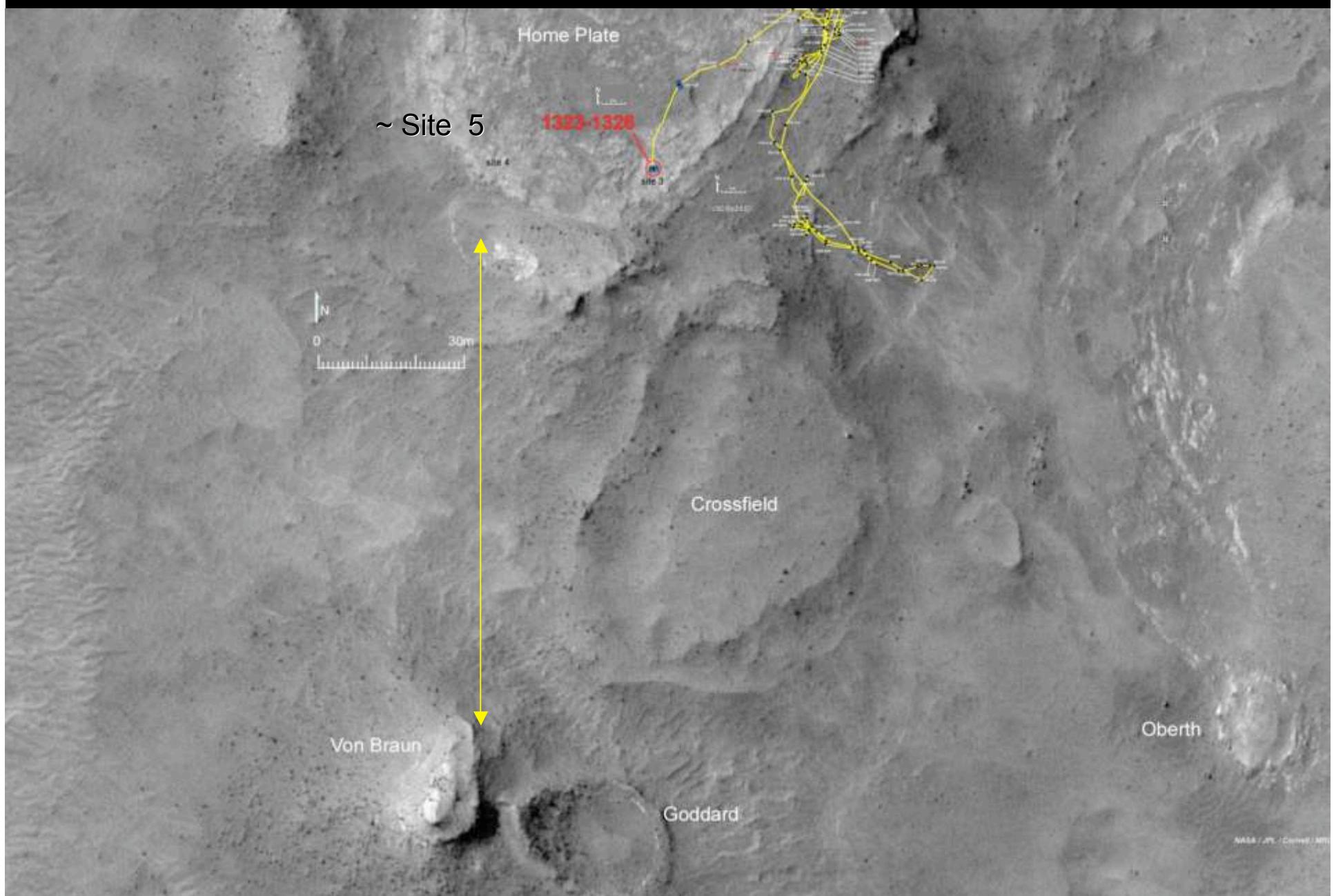
Exploration - Landis

Where we are now!



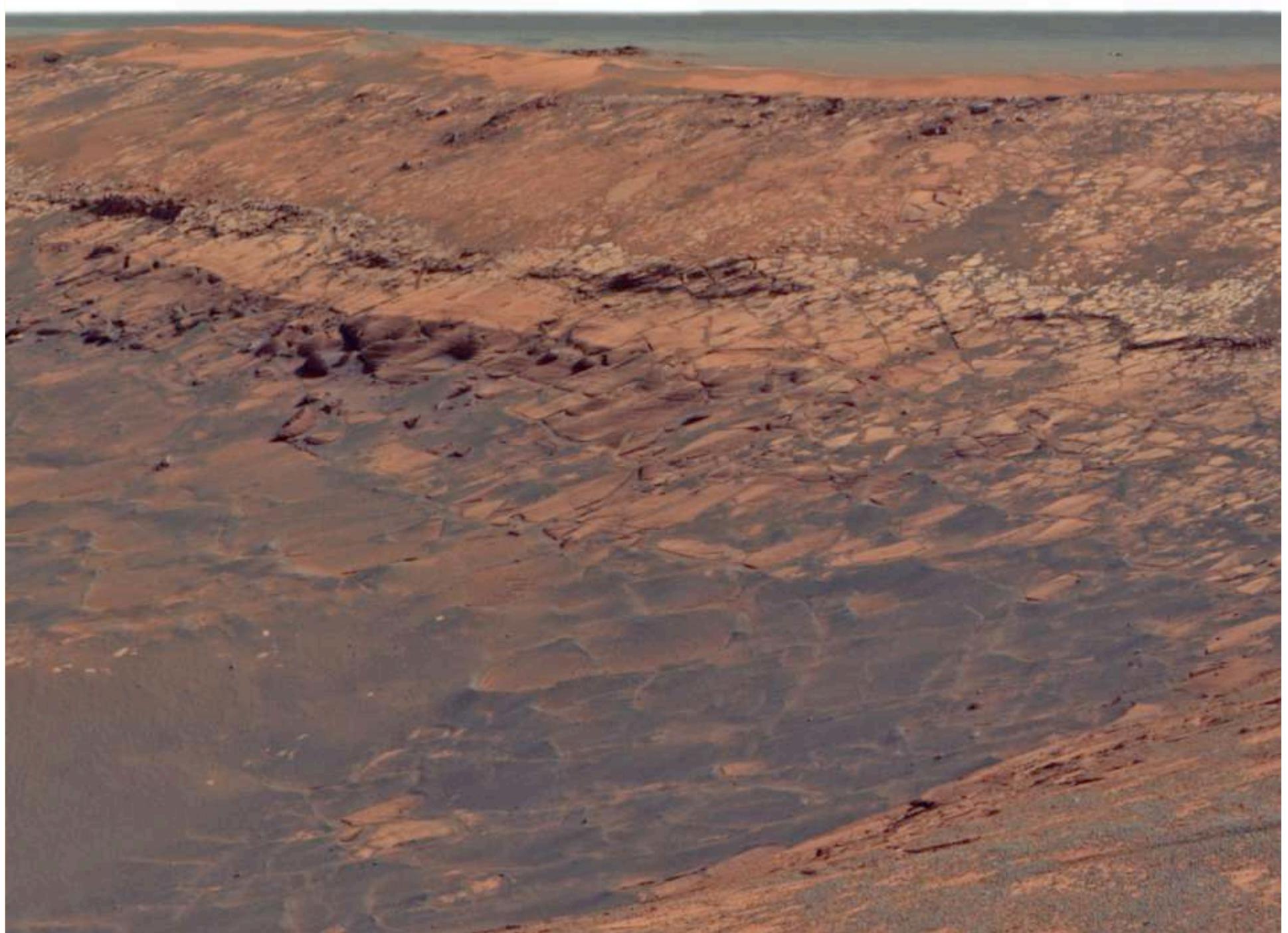
RSVP

Long term plans: new territory to the south



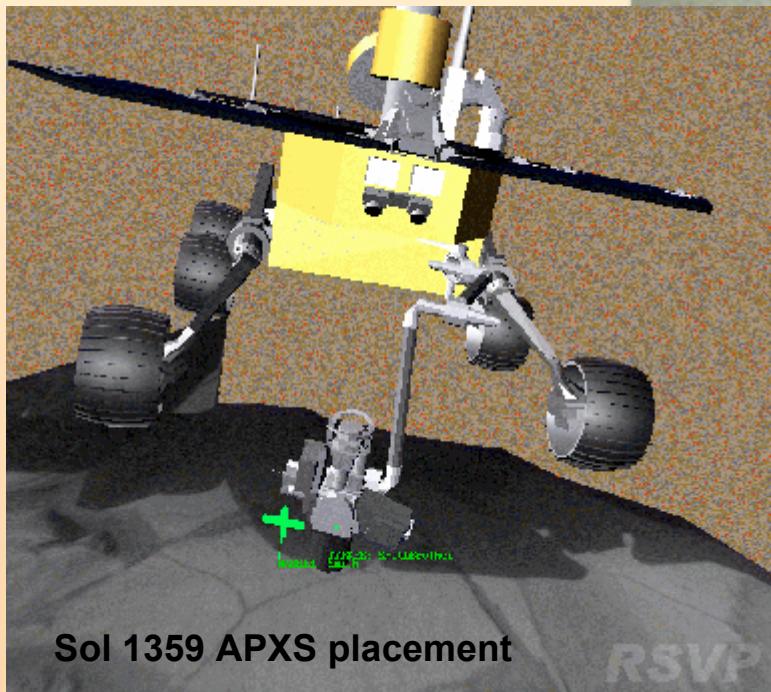
Where we are now: B





Current tasks for MER-B

New target
for RAT
brush/grind



Next landing on Mars: the Phoenix
spacecraft lands, May 25 2008

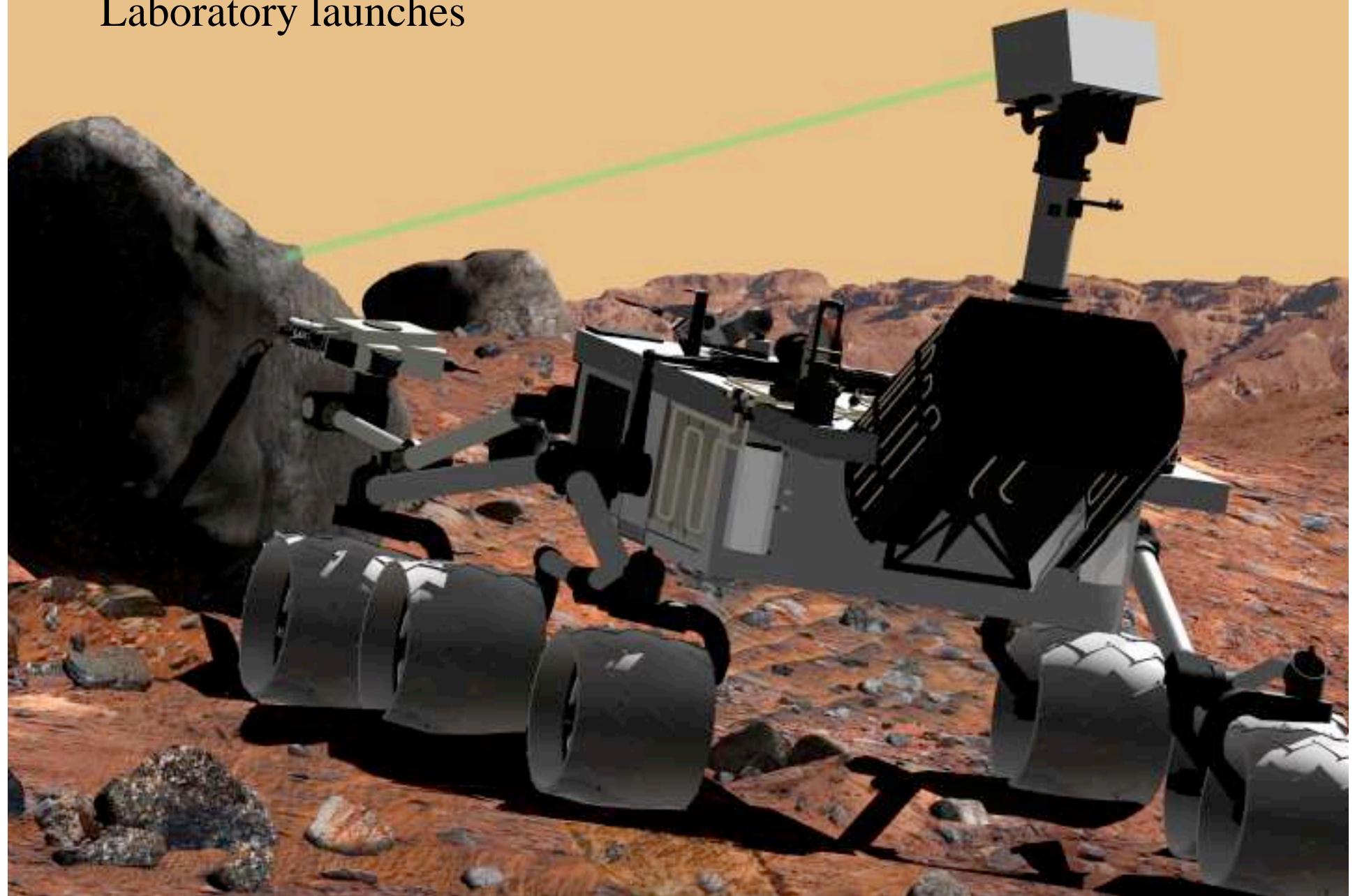


Phoenix spacecraft

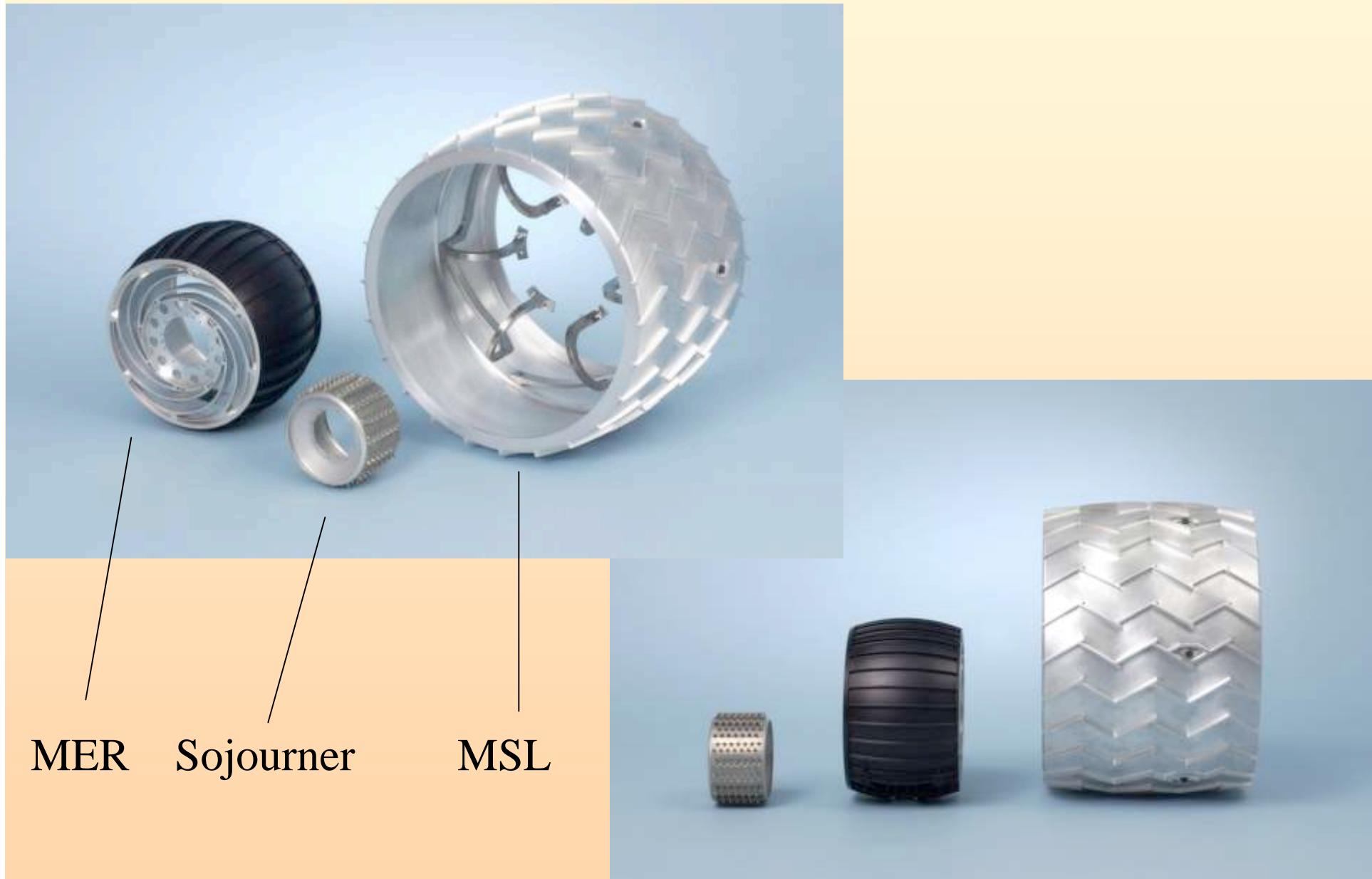


Exploration - Landis

2009: Mars Science
Laboratory launches



Wheel comparisons



MER Sojourner

MSL

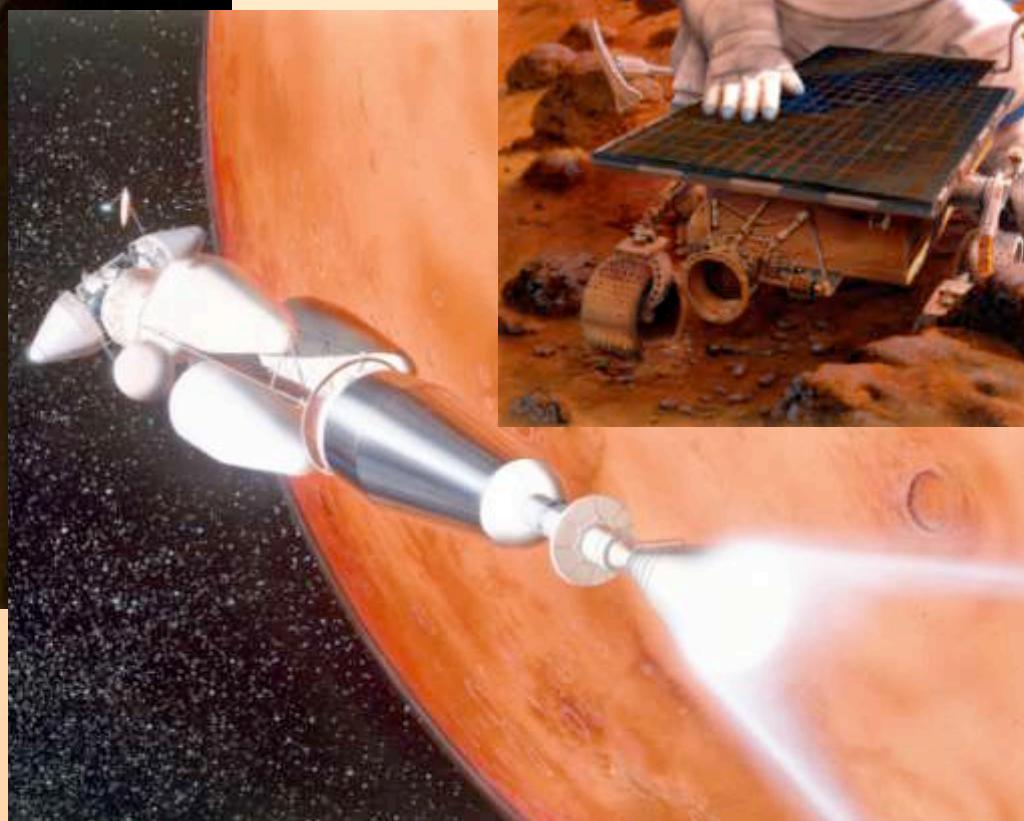
Future Mars rover?



Exploration - Landis



Launching humans to Mars



indis



Pressurized rover

Exploration - Landis



Future Mars habitat

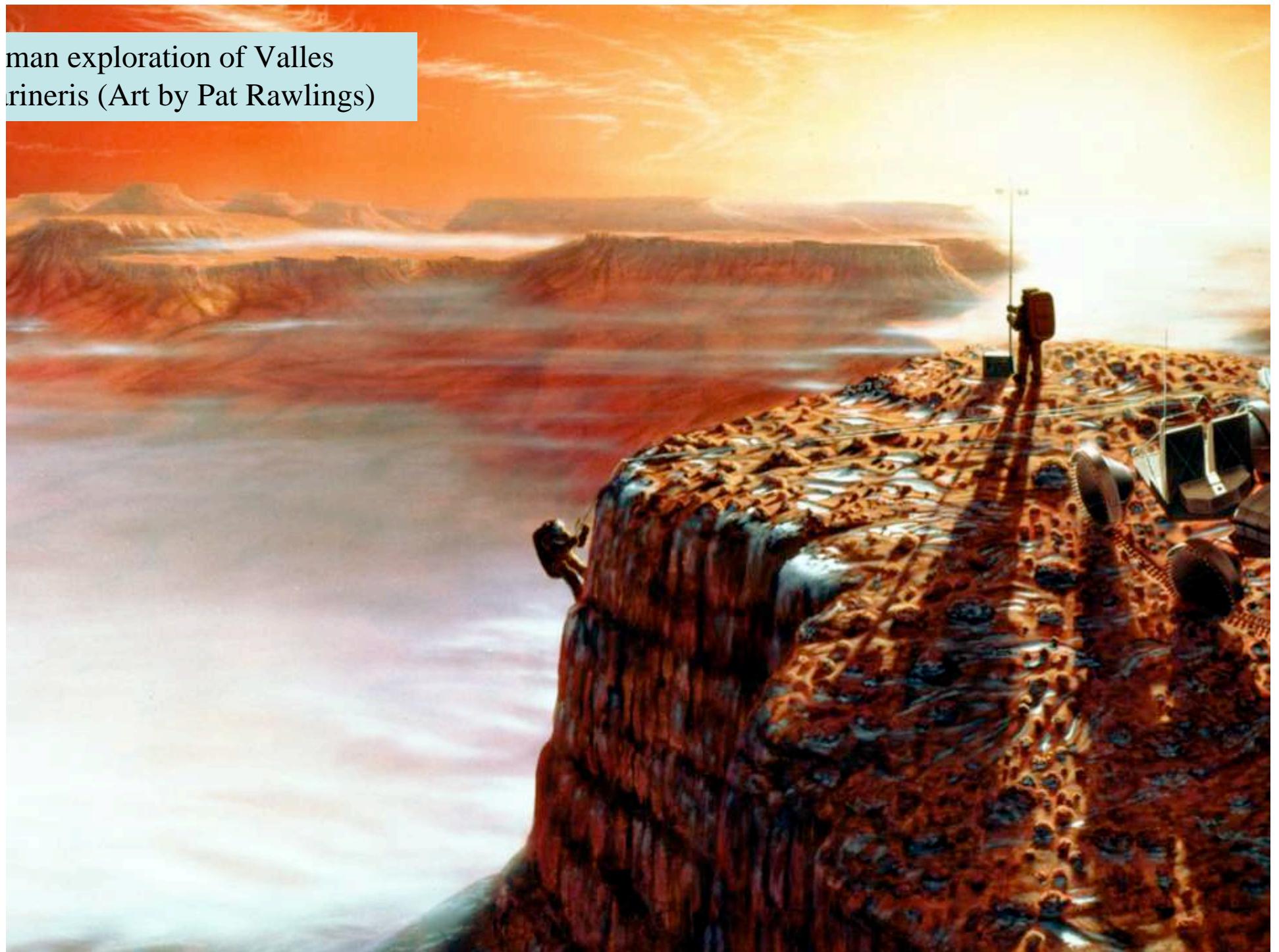
Exploration - Landis

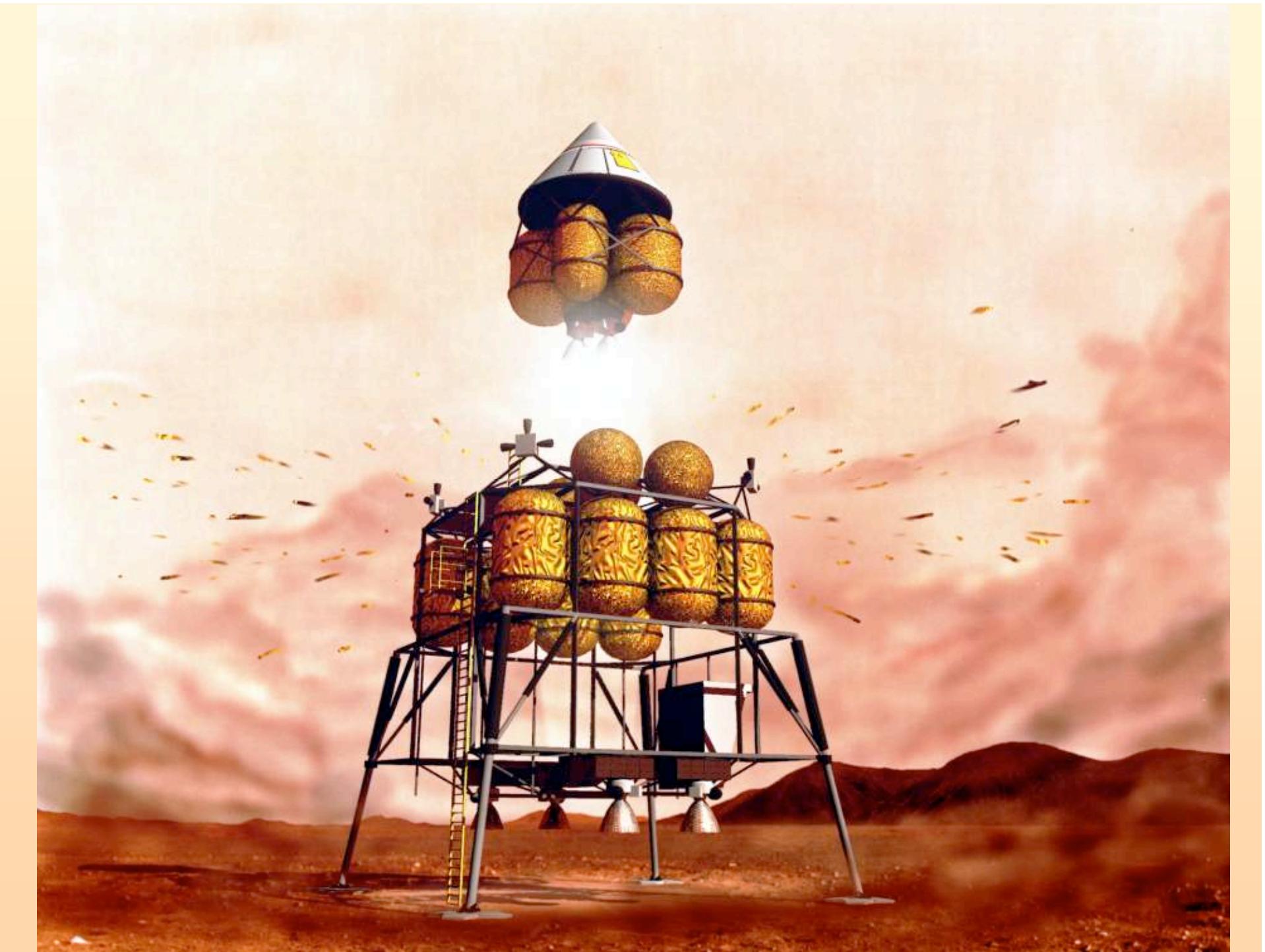


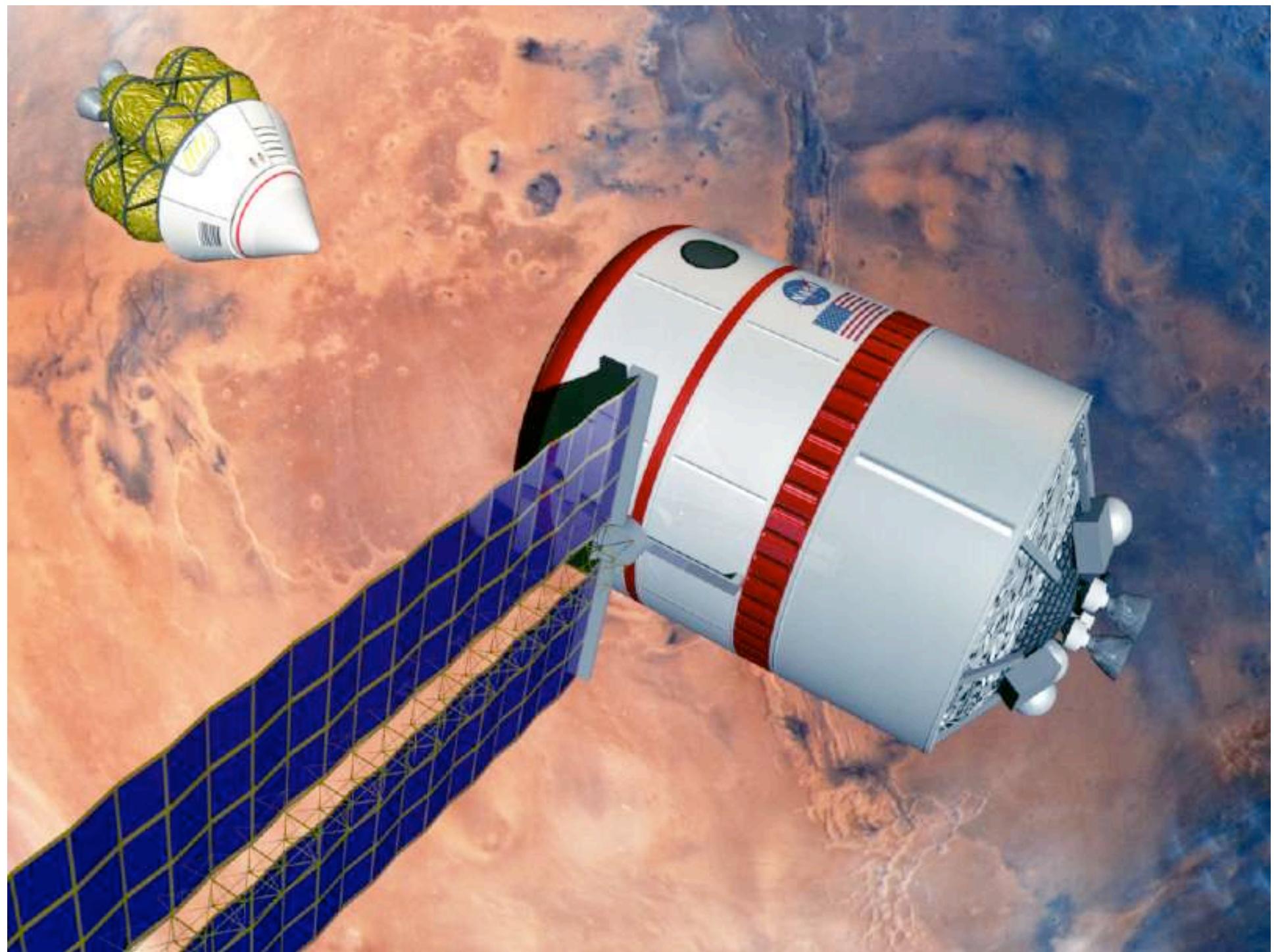
Valles Marineris

Exploration - Landis

man exploration of Valles
Marineris (Art by Pat Rawlings)







Returning safely to Earth...



Web sites

- Mars Rovers:

- Mars.jpl.nasa.gov

- Planetary Information

pds.jpl.nasa.gov/planets

